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EPA PROGRAM STATUS REPORT: Oil Shale *1979 Update*

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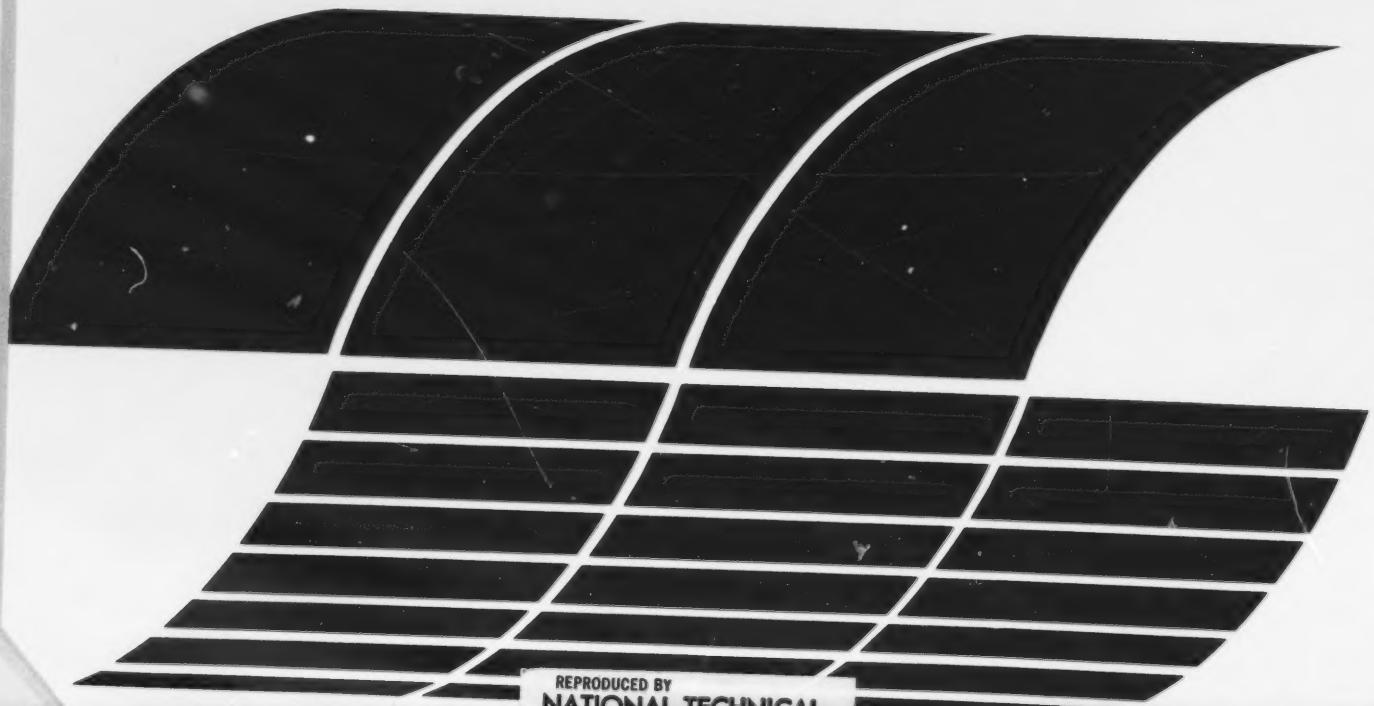
Program Report



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This report has been assigned to the INTERAGENCY ENERGY-ENVIRONMENT RESEARCH AND DEVELOPMENT series. Reports in this series result from the effort funded under the 17-agency Federal Energy/Environment Research and Development Program. These studies relate to EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy systems. The goal of the Program is to assure the rapid development of domestic energy supplies in an environmentally-compatible manner by providing the necessary environmental data and control technology. Investigations include analyses of the transport of energy-related pollutants and their health and ecological effects; assessments of, and development of, control technologies for energy systems; and integrated assessments of a wide range of energy-related environmental issues.

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March 1979

EPA PROGRAM STATUS REPORT:
Oil Shale
1979 Update

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FOREWORD

The U.S. Environmental Protection Agency is involved in oil shale research and development through projects for which it provides funds, and by staying abreast of projects funded by other governmental and industrial sources. Research provides data for defining ecological and health effects and for developing cost-effective control technology that can be used by government and industry to minimize degradation of the environment.

This report presents the status of current EPA projects related to oil shale research and development.

ACKNOWLEDGMENTS

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We wish to acknowledge with thanks the efforts of Paul E. Mills, IERL-Ci, William N. McCarthy, Jr., OEMI Headquarters, and Thomas J. Powers, III, IERL-Ci, who served, respectively, as project officer, publisher and coordinator, and assistant to both the project officer and publisher.

The support of Cameron Engineers of Denver, Colorado, for the update to "World Resources and Development History", Appendix C, is appreciated.

A special thanks to Mr. George Rey, OEMI Headquarters, for his help on the revised Glossary, Appendix F.

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TABLE OF CONTENTS

	Page
Executive Summary	vii
CHAPTERS	
1. INTRODUCTION	1
1.1 Background	1
1.2 Rationale	1
2. PROGRAM OVERVIEW	3
2.1 Overall Assessments	3
2.1.1 Pollution Control Guidance for Oil Shale Development	3
2.1.2 EPA/Industry Forum	6
2.1.3 EPA Oil Shale Symposium: Sampling, Analysis and Quality Assurance	6
2.1.4 Integrated Assessments	6
2.2 Extraction and Handling	6
2.3 Processing	6
2.4 Energy-Related Processes and Effects	7
2.4.1 Health Effects	7
2.4.2 Ecological Effects	7
2.4.3 Measurement and Monitoring	8
2.4.4 Environmental Transport Processes	8
2.5 End Use	8
3. CURRENT PROGRAM STATUS	9
3.1 Overall Assessments	9
3.1.1 Pollution Control Guidance for Oil Shale Development	9
3.1.2 EPA/Industry Forum	9
3.1.3 EPA Oil Shale Symposium: Sampling, Analysis and Quality Assurance	9
3.1.4 Integrated Assessments	9
3.2 Extraction and Handling	12
3.3 Processing	14
3.4 Energy-Related Processes and Effects	17
3.4.1 Health Effects	17
3.4.1.1 General Supportive Studies	17
3.4.1.2 Pollutant Analysis Studies	18
3.4.1.3 *In Vivo* Studies	18
3.4.1.4 *In Vitro* Studies	21
3.4.2 Ecological Effects	24
3.4.3 Measurement and Monitoring	24
3.4.3.1 Air Monitoring	24
3.4.3.2 Water Monitoring	25
3.4.3.3 Instrumentation Development	28
3.4.3.4 Monitoring Methods for Characterizing Water Pollutants	28
3.4.3.5 Development of Techniques for Measurement of Organic Water Pollution	29
3.4.3.6 Development of Ambient Monitoring Guidelines	30
3.4.4 Environmental Transport Processes	30
3.5 End Use	31
3.5.1 Shale Oil Refining	31
3.5.2 Exhaust Emissions from Shale Derived Fuel Oils	32

TABLE OF CONTENTS
(Continued)

		Page
FIGURES		
1.	Principal Oil Shale Deposits of the U.S.	2
2.	The EPA Oil Shale Work Group	4
3.	EPA Oil Shale FY 1977 and 1978 Funding Summaries	5
4.	EPA Meets with the Oil Shale Industry to Foster Communications and Cooperative R&D Efforts	10
5.	EPA Reaffirms its Commitment to Support the National Energy Plan	11
6.	Testing the Effects of Shale Dust on Animals	20
TABLE		
1.	Current Program Status Summary	35
APPENDICES		
A	EPA Published and To-Be-Published Reports on Oil Shale	
B	General References on Oil Shale	
C	World Resources and Development History	
D	Pollution Control Guidance for Oil Shale Development: Abstract and Table of Contents	
E	Abbreviations	
F	Glossary	
INDEX		

Executive Summary

The U.S. Environmental Protection Agency's (EPA) Office of Energy, Minerals and Industry (OEMI) was established in 1975 to assure that our national energy goals are matched with an effective research and development program in the critical area where energy needs and environmental protection goals overlap. OEMI implements and coordinates EPA's energy related environmental/industry research and development efforts and also serves as the overall manager of the comprehensive Interagency Energy/Environment Research and Development Program. This program has established a mechanism to plan, coordinate, and fund research and development for clean energy use and pollution control technology activities within the seventeen (17) participating governmental agencies. Since the western states in EPA's Region VIII contain major energy resources, including oil shale, the Region VIII Office works very closely with OEMI to plan and utilize the results from the R&D Energy Program. (These western states are Colorado, Montana, North Dakota, South Dakota, Utah and Wyoming.)

EPA plays an active role in many areas of oil shale research and development. EPA is maintaining a close surveillance on the projects of other Federal agencies in order to preclude duplication and to stimulate programs which can be applied to the technological advancement of an oil shale industry, while maintaining the environmental integrity.

The Program has been organized into five major catagories. Listed in the order of decreasing budgets as of the 1978 fiscal year, they are Energy-Related Processes and Effects, Processing, Overall Assessments, Extraction and Handling, and End Use. The energy-related processes and effects catagory has four significant subdivisions: health effects, ecological effects, measurement and monitoring, and environmental transport studies.

The total budget in support of the EPA Oil Shale Program in Fiscal Year (FY) 78 was $3.76 million as compared to $3.14 million in FY 77. Although the funding by category for FY 1979 is presently not available, the magnitude of the effort is currently only slightly larger than for FY 1978. An influx of funds into the program could be expected, however, if the commercialization of our nation's oil shale reserves is given primary importance in the National Energy Plan-II, scheduled for release in April of 1979. The agencies participating in this program include: the Department of Energy, U.S. Geological Survey, National Bureau of Standards, U.S. Department of Agriculture, the Department of Navy, and the National Institute of Environmental Health Sciences.

Within EPA ten separate laboratories conduct or contract oil shale-related environmental studies. The Office of Energy, Minerals and Industry, Headquarters, acts as coordinator for the Interagency Program, but has also contracted work in the area of overall assessments. OEMI's Industrial and Environmental Research Laboratory in Cincinnati (IERL-Ci) funds and manages research on processing, overall assessments, and extraction and handling. Research laboratories in Ada, Oklahoma; Athens, Georgia; Duluth, Minnesota; Las Vegas, Nevada; and Research Triangle Park, North Carolina conduct research studies in the processes and effects area. Shale oil product (end use) studies are managed and funded by both OEMI's Industrial Environmental Research Laboratory at Research Triangle Park (IERL-RTP) and the Ann Arbor (Michigan) Emission Control Technology Division (ECTD) of the Office of Air, Noise and Radiation.

Specific objectives of the EPA Oil Shale program are two-fold: first, the program is to support the regulatory goals of the Agency; second, the research is to be directed towards ensuring that any oil shale industry to be developed will be accomplished in the most environmentally acceptable manner that is reasonably possible. To these ends, EPA is continuing to assess the research needs and environmental concerns expressed by the Department of Energy (DOE) and the oil shale industry.

Research is being directed to find solutions for the environmental problems expressed by the Department's Laramie Energy Technology Center, and the active developers. The Office of Research and Development/EPA is focusing on those efforts identified by the Laramie Center, since Laramie has the responsibility within DOE for managing and developing the national effort for oil shale development.

The major thrust and accomplishments over the past year have included: one, the development of a pollution control guidance document which will serve primarily to communicate EPA regulatory policy to the oil shale developers on a comprehensive basis, as well as suggest ranges of discharge and emission limits within which the industry should strive to operate; and two, the formalization of an interaction with industry in the form of a forum for the purpose of not only transferring to industry the results of EPA-sponsored research but also catalizing cooperative research in the environmental areas of mutual interest.

EPA PROGRAM STATUS REPORT:
OIL SHALE

1. INTRODUCTION

This report provides an overview of current oil shale research and development (R&D) efforts being performed by the Environmental Protection Agency (EPA), or funded by EPA money passed-through to other federal agencies under the Interagency Energy/Environment R&D Program. This chapter introduces the background and rationale behind EPA's efforts. Chapter 2 discusses EPA program goals and fiscal year (FY) 1977 program funding. The scope-of-work for ongoing projects and a table summarizing these efforts are presented in Chapter 3.

1.1 BACKGROUND

Since its establishment in 1970, EPA has been involved in energy-related environmental research efforts, including the development of pollution control technologies designed to eliminate the adverse effects that are often by-products of energy conversion.

The recent national policy emphasis on the development of domestic energy supplies stimulated the formation of an Office of Energy Research (OER) by EPA in late 1974. The OER was established within the Office of Research and Development (ORD). Reorganization of ORD in June 1975 combined industrial and mineral extraction pollution control research with energy-related environmental research in a new Office of Energy, Minerals and Industry (OEMI).

OEMI provides a focus for EPA's own environment/energy/industry R&D efforts and coordinates the comprehensive Federal Interagency Energy/Environment R&D Program. This program is a seventeen-agency effort whose goals include: environmental protection during every phase of accelerated development and use of energy supplies, with emphasis on domestic resources; and, the development of cost-effective pollution control technologies for energy, industry, and mineral extraction and processing systems.

Region VIII is in the forefront of the energy-related environmental protection activities, particularly in the permit application procedures, which places the Region VIII office in communication with many federal, state, and industrial personnel.

1.2 RATIONALE

Our cheap and abundant energy supplies are rapidly being depleted. Domestic reserves of oil and natural gas have been declining since 1970, and imported oil and gas are growing increasingly more expensive. U.S. vulnerability to supply interruption has also increased. By the mid-1980's, the U.S. could be vying for scarce oil against its allies and other consuming nations, causing even greater price increases and pressure on the world oil supply.

Consequently, the U.S. must significantly reduce its reliance on imported oil and gas, and make greater use of domestic energy resources. The present energy mix consists of crude oil, natural gas, coal, hydroelectric power, and some geothermal power. There is considerable R&D activity in other energy sources such as solar, tar sands, synthetic oil and gas from coal, and oil shale.

The principal known oil shale deposits of the U.S. are shown in Figure 1. The richest of the deposits is the Green River Formation of Colorado, Utah, and Wyoming. This region contains the largest single known concentration of hydrocarbons in the world. If only that portion of the Green River Formation containing the equivalent of 25 gallons (or more) of oil per ton of shale were mined, it has been reliably estimated that the shale oil in-place would amount to about 731 billion barrels of oil.

Because western oil shale is a domestic energy resource of considerable magnitude, the availability of large quantities of crude shale oil for refining products such as gasoline, diesel, and jet fuels could sharply expand the U.S. energy supply. Current R&D work is oriented toward finding an economically and environmentally practical way of producing shale oil and bringing it to market.

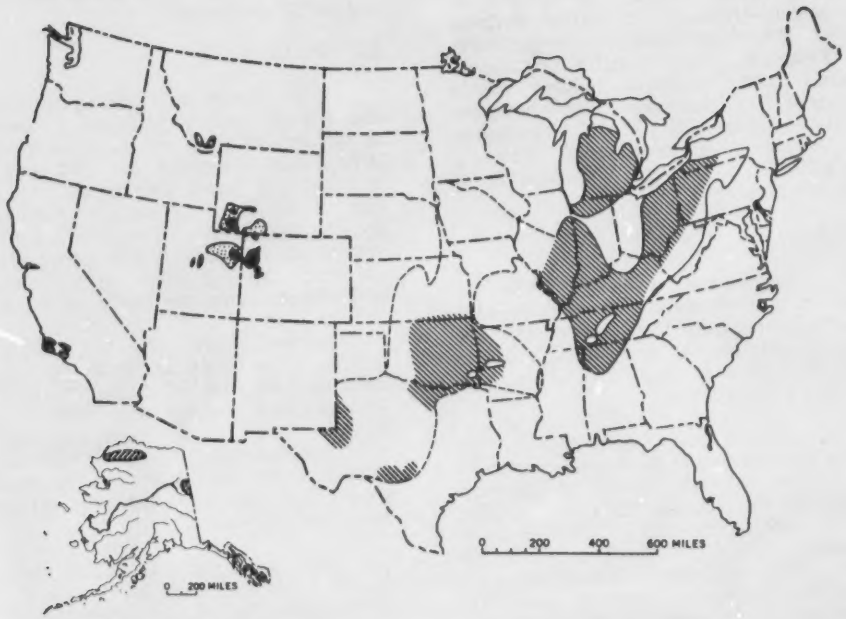


Figure 1.

PRINCIPAL OIL SHALE DEPOSITS OF THE U.S.

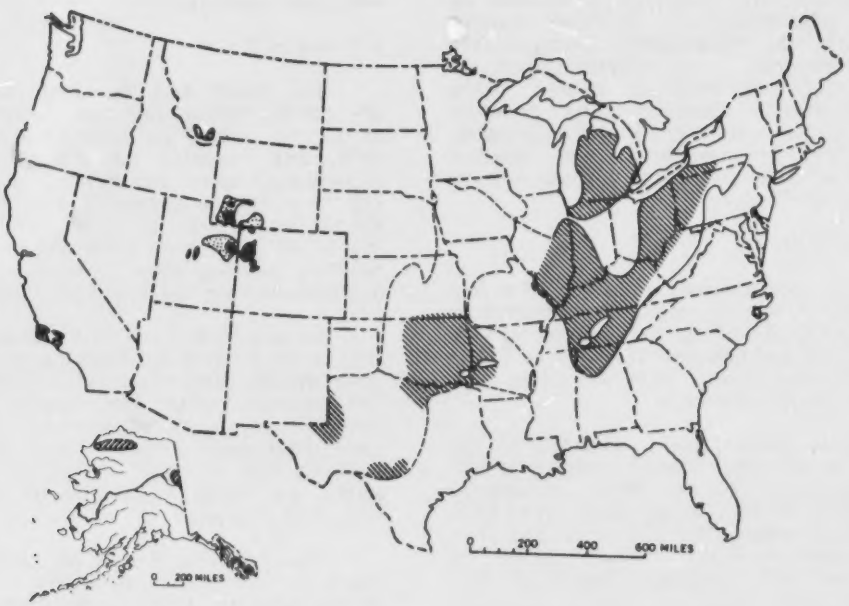
Explanation

Tertiary deposits: Green River Formation in Colorado, Utah, and Wyoming; Monterey Formation, California; middle Tertiary deposits in Montana. Black areas are known high-grade deposits.

Mesozoic deposits: Marine shale in Alaska.

Permian deposits: Phosphoria Formation, Montana.

Devonian and Mississippian deposits (resource estimates included for hachured areas only). Boundary dashed where concealed or where location is uncertain.



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2. PROGRAM OVERVIEW

EPA studies related to the development and commercialization of oil shale are providing information on health and ecological effects from pollutants created by the extraction and processing of oil shale, and on technological methods that can be used to control the release of those pollutants. The program is also assessing the environmental impact of the use of the fuels refined from shale oil. These efforts are principally supported by funds from the seventeen-agency Federal Interagency Energy/ Environment R&D Program.

Studies under these programs relate to EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy systems. The goal of the program is to assure the rapid development of domestic energy supplies in an environmentally compatible manner by providing the necessary environmental data and control technology.

Through its efforts of managing and coordinating the program, as well as implementing a portion of the effort, EPA is developing an oil shale industry that will be economically and environmentally sound, utilizing the best and most practical control technologies.

Within EPA, the Oil Shale Work Group (OSWG) is responsible for assuring a coordinated and integrated approach to oil shale R&D efforts. Formed in 1975 by OEMI, the OSWG consists of individuals selected from EPA Research Laboratories and Program Offices who have environmental responsibilities associated with oil shale development. The OSWG provides EPA with technical expertise for up-to-date information on oil shale development and its environmental impact at the policy/decision-making level. OSWG is also responsible for reviewing EPA's overall environmental research strategy associated with federal and commercial oil shale development and for exploring avenues of cooperative environmental research between industry and the government. Figure 2 shows members of the OSWG.

OEMI's oil shale R&D activities are coordinated by EPA. EPA's oil shale program is administered by the Office of Energy, Minerals and Industry within the Office of Research and Development. The overall effort is presently divided into five subprogram areas:

- Overall Assessments
- Extraction and Handling
- Processing
- Energy-Related Processes and Effects
- End Use

The remainder of this chapter examines each of these areas as it relates to oil shale R&D, and discusses its program funding. Total funding for FY 1978 EPA oil shale efforts is $3,760,000. At the end of this chapter, Figure 3 shows EPA funding and pass-through funding for the oil shale program by subprogram category for Fiscal Years 1977 and 1978.

2.1 OVERALL ASSESSMENTS

The overall assessment program was established to define and evaluate the various environmental and socioeconomic effects that result from energy extraction, processing, transportation, conversion, and end use activities. Objectives of the program include: identification of energy supply and conversion alternatives; evaluation of the cost/risk/ benefit trade-offs of energy production, conservation, and pollution control alternatives; assistance to the nation in the selection of optimized policies for the attainment of energy and environmental quality goals; and, identification of critical gaps in current energy-related research programs, and of other priority research topics, which must be addressed to support direct EPA responsibilities.

2.1.1 Pollution Control Guidance for Oil Shale Development

The EPA Oil Shale Work Group is preparing a report entitled, "Pollution Control Guidance for Oil Shale Development." The purpose of this report is to provide environmental guidance for the emerging oil shale industry. The report is intended to serve as a reference and guide to regulators, developers, and others who are or will be involved with the oil shale industry. It is expected that the report will be published in three volumes: an executive summary, the main report, and a volume of appendices.

This report will convey EPA's understanding and perspective of oil shale development by providing a summation of available information on oil shale resources; a summary of major air, water, solid waste, health, and other environmental impacts; an analysis of potentially applicable pollution control technology; a guide for the sampling, analysis, and monitoring of emissions, effluents, and solid wastes from oil shale processes; suggestions for development of interim standards for emissions, effluents, and solid waste disposal; and a summary of major retorting processes, emissions, and effluents.

Figure 2.

THE EPA OIL SHALE WORK GROUP

The group, including two associate members from the USGS Area Oil Shale Office, most recently met in Denver in conjunction with the January 1979 meeting of EPA's Office of Energy, Minerals and Industry held with industry.

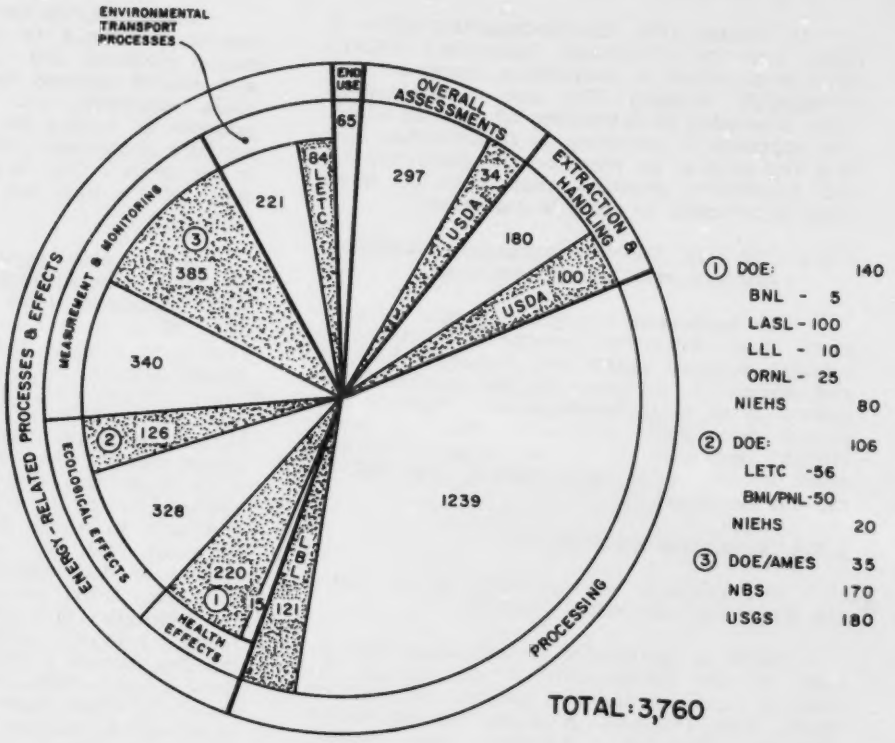
Back Row: Eugene Harris, IERL-Cin, Chairman; Edward R. Bates, IERL-Cin; Wesley L. Kinney, EMSL-Las Vegas; Les G. McMillion, EMSL-Las Vegas.

Middle Row: Robert Thurnau, IERL-Cin; Mark Mercer, OSW; Bruce Tichenor, IERL-RTP; Alden Christianson, IERL-Cin.

Front Row: Miles LaHue, USGS; Glen A. Miller, USGS; Paul Mills, IERL-Cin; and William N. McCarthy, Jr., OEMI, Washington, D.C.

In attendance but not pictured were Kenneth Biesinger, ERL-Duluth; David Coffin, HERL-RTP; Robert Newport; R. S. Kerr, ERL and Terry Thoem, Region VIII (Denver).

FY 1978



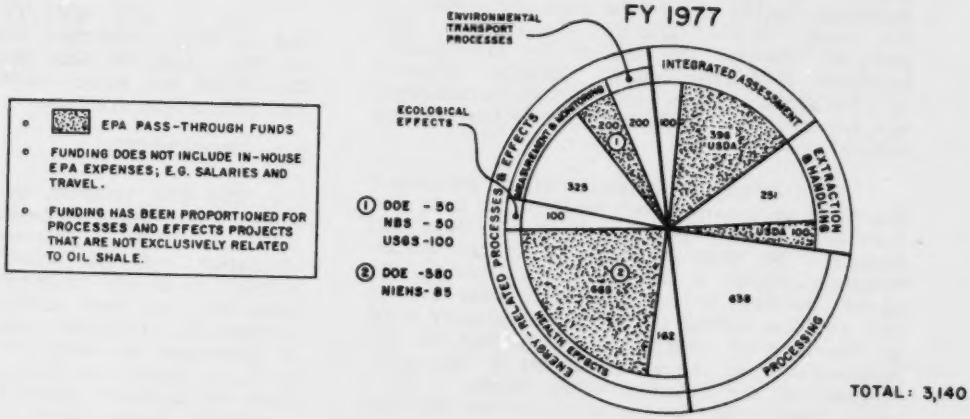


Figure 3

EPA OIL SHALE FY 1977 AND 1978 FUNDING SUMMARIES

(in thousands of dollars)

2.1.2 EPA/Industry Forum

In October 1978, the headquarters office of OEMI and its Cincinnati Laboratory (IERL) initiated an effort to establish a closer working relationship between EPA and the industrial firms interested in developing oil from oil shale. The approach is centering on two meetings with industry to gain its ideas on the environmental and regulatory problems that must be faced prior to bringing oil shale to commerce.

2.1.3 EPA Oil Shale Symposium: Sampling, Analysis and Quality Assurance

The symposium brought research, government, and industry personnel together to present technical papers and exchange thoughts and knowledge pertinent to the environmental control of oil shale development. Emphasis was placed on quality assurance, sampling techniques, and analysis in the areas of air and water quality, solid waste control, and biological and health effects.

2.1.4 Integrated Assessments

Two projects are currently active under the integrated assessment program.

USDA is performing a technology assessment of the development of six energy resources (coal, geothermal, natural gas, oil, oil shale, and uranium) in eight western states (Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming) during the period from the present to the year 2000. Energy development was analyzed through the use of six site-specific scenarios (Colstrip, Beulah, Gillette, Kaiparowits/Escalante, Rifle, and Navajo/Farmington) and two regional scenarios representing low and nominal demand cases.

A University of Oklahoma study addressed energy development water problems in both the Northern Great Plains and Rocky Mountain Region. Oil shale development in the Rocky Mountain Region is highly concentrated in the upper reaches of the Colorado River Basin. One problem facing the oil shale industry here is the lack of water availability due to the fragmentation of the water market in the upper reaches of the Colorado River Basin. Three states hold rights to the water, while Colorado (the state with the greatest share of oil shale) has the least undepleted surface water flows. While it seems likely that water rights can and are being bought from agriculture, the very localized nature of the oil shale industry seems to indicate that agricultural production in certain areas near the Piceance Basin may be drastically reduced as a result of the sale of water rights to the oil shale industry.

2.2 EXTRACTION AND HANDLING

EPA's program for oil shale extraction and handling attempts to assess potential environmental problems and develop resource handling and control methods for in situ and surface oil shale extraction and land reclamation. This program is needed in order to define environmentally acceptable practices for the extraction of oil shale. The semiarid and arid oil shale areas of the West will be extremely difficult to restore.

Work being performed involves assessing the potential environmental impact upon air and water resources from the extraction and handling of oil shale resources. Also included are studies of disposal and revegetation of spent oil shales.

Three projects are underway to determine surface stability, water movement and runoff, water quality, and revegetation of spent oil shale from the TOSCO II, Paraho Direct, and USBM retorting processes. Another project is underway to assess the environmental impact of leachates from raw mined oil shale. A fifth project is determining the nature, quantities, and composition of fugitive dust emissions in the vicinity of mining operations, haulage roads, crushing operations, and spent shale transfer points. Another project is analyzing trace element composition in two cores from the Naval Oil Shale Reserve. A seventh project is underway to assess air emissions from old oil shale waste sites.

For FY 1979, $211,000 has been spent on the oil shale extraction and handling program. Of this, $100,000 was passed-through EPA to the USDA for water quality work on surface and subsurface drainage.

2.3 PROCESSING

The EPA program for processing seeks to ensure that future large-scale commercial applications of oil shale processing, combustion, and utilization can be constructed and operated within required environmental limits. The program's approach includes an environmental assessment, evaluation, and testing of a number of processes in order to (1) define the best available control technology, (2) prepare standards-of-practice manuals, and (3) support standards-setting efforts.

The processing program at IERL-Ci has sponsored research in the areas of: (1) environmental characterization; (2) environmental analytical methods development; (3) assessment of wastewater treatment and control technology; (4) air pollution control of oil shale retorting; (5) overview of environmental problems; and

(6) preliminary oil shale pollution control guidance. The overall objective is to define environmental problems early in the process development phase and to then develop effective pollution control technologies to abate the problems identified.

2.4 ENERGY-RELATED PROCESSES AND EFFECTS

The energy-related processes and effects program is designed to identify the mechanisms of movement within the environment and the effects on human, animal, and plant populations which are associated with energy-related activities. The goal of the program is to compile and evaluate information to support decisions relative to the protection of natural biota, human health, welfare, and social goals. This program includes four areas that are directly involved in oil shale R&D: health effects; ecological effects; measurement and monitoring, and environmental transport processes.

2.4.1 Health Effects

The health effects research program seeks to determine the hazards from pollutants released by various energy technologies. The program includes the development of bioassay and other techniques to measure hazards, and the application of these techniques to the characterization of hazards to human health. In relation to human health, the emphasis of the program is on the effects of agents which give rise to carcinogenesis, mutagenesis, teratogenesis, toxicity, and disorders of the cardiopulmonary system.

A variety of pollutant species are being examined for their impacts on human health. Research efforts have confirmed that pollutants such as sulfur and nitrogen oxides and their atmospheric reaction products are detrimental to human health.

Another major effort has been to assess the potential health impacts of developing energy technologies. Although a number of preliminary assessments have been made, most of the data are derived from processes in the early stages of development. It is acknowledged that standard-setting information must be based upon extrapolation of bench and pilot scale data to the commercialization stage. This developmental work also provides guidance to industry on the anticipated environmental regulations in order to avoid sudden and expensive equipment alterations.

Other work involves a number of testing methods that have been developed or refined by research supported by EPA. These efforts include new methods of identification by means of cytological, biochemical, and physiological indicators, of the damages resulting from exposure to pollutants associated with energy development. By incorporating these techniques into a hierarchial testing methodology, EPA's health effects program has been able to efficiently allocate available research funds in the Interagency Energy/Environment R&D Program.

2.4.2 Ecological Effects

The ecological effects research program is based on the results of research conducted in other areas of the Interagency Program. Various methods and instruments developed and refined within the measurement and monitoring areas, and the results of environmental transport processes studies, are used to characterize the ecosystem effects associated with oil shale development. The various research efforts determine the effects of organic and inorganic pollutants, thermal discharges, and complex effluents on water and land ecosystems.

Current research efforts include the determination of immediate and long-term ecosystem dose-response relationships for single pollutants and combinations of pollutants released by oil shale extraction, conversion, and utilization, and the assessments of the effects of mining-related transportation systems on water, air, soil, plant, animal, and aesthetic resources.

Effects of Aqueous Effluents from In Situ Fuel Processing Technologies on Aquatic Systems

This study at the University of Wyoming is principally associated with in situ oil shale retorting and underground coal gasification. Specifically, it is directed to study the toxicity to aquatic biota. Included are effects on growth and reproduction, avoidance/preference response of aquatic organisms, bioaccumulation and metabolism in aquatic organisms, biochemical, physiological and pathological effects on aquatic organisms, and degradation and residue kinetics in model laboratory microcosms.

Chemical and Biological Characterizations of Oil Shale Processing and Coal Conversion Effluents

The Colorado State University study is to provide predictive information about the effects of pollutants from oil shale processing and coal conversion on surface waters and aquatic biota. The three areas of investigation are: chemical characterization of effluents and by-products associated with each of the above energy development areas; field surveys and analyses of aquatic organisms in streams which are, or may be, impacted by these effluents; and laboratory bioassays of known and potential toxicants associated with these effluents.

The objectives of the proposed research are to determine: the chemical and biological impacts of aquifers associated with in situ oil shale retorting on surface waters; chemical

characteristics of retort process waters; chemical characteristics of retorted oil shale leachate waters; toxic materials present in oil shale process and leachate waters; degradation characteristics of oil shale retort and leachate waters; chemical and toxicological characteristics of coal gasification and tar sands process waters; and physical and chemical transformations of toxic materials from coal gasification process effluents.

For FY 1978, $134,000 has been spent on oil shale research through the ecological effects program. Work has been sponsored by EPA's Environmental Research Laboratory in Duluth, Minnesota and the Laramie Energy Technology Center.

2.4.3 Measurement and Monitoring

This research area involves the detection, measurement, and monitoring of pollutants, and the performance of quality assurance activities to characterize the ecosystem effects associated with oil shale development. The objectives are to accelerate the development of new and improved sampling and analysis methods for energy-related pollutants and to identify, measure, and monitor effluents during oil shale development activities.

2.4.4 Environmental Transport Processes

This research area is closely integrated with the research areas of measurement and monitoring, and ecological effects. Within the former research area, methods and tools are developed, tested, and applied to provide data useful in the understanding of transport and fate processes. Ecological effects studies are related to the effects of pollutants on natural organisms and their habitats. Environmental transport processes research addresses energy-related pollutants in terms of mechanisms of dispersion from sites of production, transformations which occur subsequent to release, and ultimate accumulation in man, domesticated and wild animals and plants, and in nonliving material such as soil and sediments.

Current efforts are underway to develop methods to predict groundwater changes resulting from mining activity. Presently, the information being generated is in the area of coal strip mining, but the methods will be extrapolated to include oil shale retorting. Efforts in 1978 and 1979 will concentrate on oil shale.

Funding for the environmental transport processes program was $200,000 for FY 1977. Funds went to EPA's R. S. Kerr Environmental Research Laboratory.

The measurement and monitoring program is defining baseline environmental conditions and is analyzing the impacts of energy development on the environment by the identification, measurement, and long-term sensing of air, land, and water quality. The various research efforts investigate organic and inorganic pollutants, thermal discharges and complex effluents on water and land ecosystems.

Another important aspect of this program is quality assurance. The data that are collected on environmental pollutants must be valid and reliable, so a separate subprogram was designed to guarantee data accuracy. The quality assurance activities seek to insure that a common acceptable methodology be used by all entities who perform monitoring so that data may be compared.

2.5 END USE

The end use studies focus on potential environmental problems which could be generated through the refining and combusion of shale oil. To date the research has focused primarily on the generation of NO_x due to the high Nitrogen content of the shale oil.

3. CURRENT PROGRAM STATUS

Each EPA funded project falls under a category described in Chapter 2 of this report. The same is true for projects supported by EPA pass-through funds. Table 1 on page 35 summarizes the status of EPA's current oil shale program.

3.1 OVERALL ASSESSMENTS

3.1.1 Pollution Control Guidance for Oil Shale Development

This report summarizes the anticipated EPA regulatory approach toward oil shale development and is designed to serve as a reference and guide to EPA offices, federal agencies, and private developers involved with the emerging oil shale industry. Volume 1 contains seven sections: Introduction; Recommendations; Environmental Impacts; Pollution Control Technology; Sampling, Analysis, and Monitoring of Emissions, Effluents, and Solid Wastes; Suggestions for Development of Interim EPA Emissions, Effluents, and Solid Waste Disposal Standards; and Summary of Major Retorting Processes, Emissions, and Effluents. Volume 2 contains six appendices: State-Of-The-Art of Oil Shale Development; Procedures for Ambient Air Monitoring; Past, Present, and Future Baseline Monitoring Activities; Applicable Federal, State, and Local Laws and Regulations; List of Analytical Procedures Manuals and Quality Assurance Manuals; and Catalog of Existing Federal, State, and Locally Required Permits.

3.1.2 EPA/Industry Forum

In October 1978, the headquarters office of OEMI and its Cincinnati Laboratory (IERL-Ci) initiated an effort to establish a closer working relationship between EPA and the industrial firms interested in developing oil from oil shale. The approach is centering on two meetings with industry to gain its ideas on the environmental and regulatory problems that must be faced prior to bringing oil shale to commerce. It is hoped that cooperative research directed toward solving these problems will ensue. C.K. GeoEnergy Corporation of Las Vegas, Nevada was selected as the contractor to organize and conduct both the initial and follow-up meetings with industry.

On January 23-24, 1979, in Denver, senior management from EPA's Office of Energy, Minerals and Industry representing the R&D effort, and from Region VIII, representing the regulatory function, met with senior management from industry. (Figure 4). Senior management from DOE and Department of Interior's (DOI) Area Oil Shale Office were in attendance to round out the federal sector. (Figure 5) There was also representation from the State of Colorado. Industry was represented by 25 companies. Industry heard both DOE and EPA express a positive attitude toward the prospects for oil shale commercialization. Industry appeared receptive to the idea of cooperative research. Industry was asked to make individual contacts with EPA R&D to develop cooperative efforts in those areas where environmental problems were inhibiting development. A second meeting is planned within five months to coordinate and set funding priorities for these individual efforts.

3.1.3 Oil Shale Symposium: Sampling, Analysis, and Quality Assurance

The IERL-Ci, with Denver Research Institute as grantee, sponsored a symposium in Denver, Colorado, on March 26, 27, and 28, 1979. This symposium brought together the available expertise from industry, government, and academia to provide a forum for presentation of the state-of-the-art in sampling, analysis, and quality assurance of the pollutants from oil shale developments. Interagency and industrial cooperation and information exchange was encouraged. Opinions from researchers as to the current capabilities of methods, and research needs, were presented.

The symposium information will be published and evaluated for use in developing standardized methods for oil shale environmental sampling and analysis methodology. The information will be used to develop the manual on sampling and analysis methods for oil shale described above.

Topics of the symposium included: pollutants to be characterized and quantified; media to be examined; health effects; sampling and analysis methods; quality assurance needs; future directions of methodology; reference materials; and instrumentation development.

3.1.4 Integrated Assessments

Integrated Assessment: Socioeconomic Consequences of Coal and Oil Shale Development

USDA's Economic Research Service, Washington, D.C., is working to describe current resource use in coal and oil shale extraction and to assess agricultural economic implications, resource competition, and use resulting from coal and oil shale development. This work will also estimate the impact of energy development in the Northern Great Plains on employment, income, and population of rural communities and of local government finances and services, including revenue

Figure 4.

EPA MEETS WITH THE OIL SHALE INDUSTRY TO FOSTER
COMMUNICATIONS AND COOPERATIVE R&D EFFORTS

On January 23-24, 1979 in Denver, Colorado, senior management personnel from the oil shale industry met with senior management from EPA, DOE and DOI to explore cooperative research efforts that will result in process methodology or control technology that will mitigate the environmental impacts that could result from commercializing the oil shale reserves.

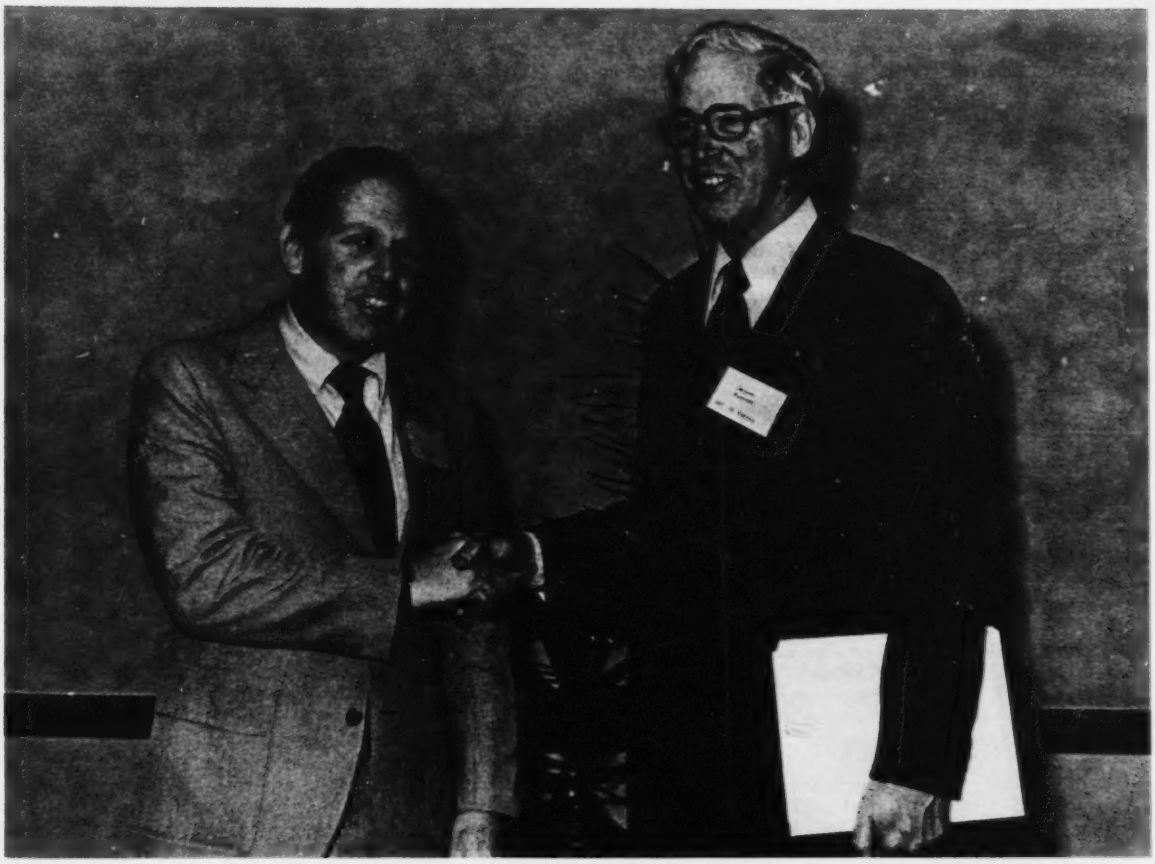


Figure 5.

EPA REAFFIRMS ITS COMMITMENT TO SUPPORT THE NATIONAL ENERGY PLAN

At the Denver EPA Industry meeting, Alan Merson, EPA Region VIII Administrator (left), discusses with Jackson Gouraud, Deputy Undersecretary for Commercialization, DOE, EPA's commitment to ensure that any commercialized oil shale industry will be environmentally acceptable to the nation. During the meeting, Gouraud and Merson each presented his agency's viewpoint concerning the development of the nation's oil shale reserves.

potential. Interrelationships of local government expenditures to employment, population, income, age structure, and other socioeconomic variables will be analyzed. The work will evaluate costs of mined land reclamation and uses for land after mining. Interregional economic implications and trade-offs for agricultural and rural areas resulting from coal development will also be evaluated. Included are effects of increased water demand for coal development on agricultural industries, environmental quality, and rural resource use. This project is funded by EPA pass-through funds to USDA. The duration of this project is from March 1976 to June 1979.

Technology Assessment of Western Energy Resource Development

The University of Oklahoma is under contract to determine the effects of development of six energy resources in the western U.S. The energy resources under study are: coal, geothermal, natural gas, oil, uranium, and oil shale. The study comprises an eight-state area including: Arizona, Colorado, Montana, New Mexico, North and South Dakota, Utah, and Wyoming. The results of the assessment will be used by EPA in developing pollution control policies and their associated implementation strategies applicable to western energy resource development.

Recently, the University of Oklahoma, in conjunction with Radian Corporation of Austin, Texas, released a four-volume report titled, "Energy from the West: A Progress Report of a Technology Assessment of Western Energy Resource Development," EPA-600/7-77-072. It is a progress report of a three-year technology assessment of the development of the six energy resources. The contract began in July 1975 and is scheduled for completion in late 1978.

3.2 EXTRACTION AND HANDLING

Within the extraction and handling program are four projects sponsored by EPA's Industrial Environmental Research Laboratory in Cincinnati (IERL-Ci) that are being performed by Colorado State University, Fort Collins, Colorado. Three of these projects deal with surface stability, water movement and runoff, water quality and revegetation of processed oil shale. The fourth deals with assessing the environmental impact of leachates through raw mined oil shale. A project being conducted by the USDA using EPA pass-through funds is developing recommendations for revegetation following oil shale mining. Another study is being conducted by TRW, Inc., Redondo Beach, California, which analyzes the mining and handling operations and the fugitive dust emitted at the Paraho site in Colorado. Two projects are being cofunded with the Laramie Energy Technology Center, DOE. The first being performed by the Lawrence Berkeley Laboratory, University of California, Berkeley, California, is analyzing trace element composition in two cores from the Naval Oil Shale Reserve. The second being performed by Science Applications, Inc., Lafayette, California, will assess air emissions from old oil shale waste sites.

Technologies for Controlling Adverse Effects of Mining on Forest, Range and Related Freshwater Ecosystems

Coordinated studies are underway to develop technologies for controlling adverse effects of mining on forest, range, and related freshwater ecosystems. The studies are being conducted by USDA Forest Service research scientists at several locations in the Northern Great Plains and Southwest U.S., by the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado; the Intermountain Forest and Range Experiment Station, Ogden, Utah; the Forest Environment Research Staff, Washington, D.C.; and the Northeastern Forest and Range Experiment Station, Upper Darby, Pennsylvania.

The work will: (1) develop guidelines and criteria for overburden drilling, analysis, and placement as related to growth-supporting media; (2) prepare technical handbooks on revegetation recommendations for new research; (3) develop guidelines and criteria for the use of nonmine wastes as soil amendments on oil shale spoils; and (4) develop recommendations, guidelines, and criteria, based on new research for revegetation following oil shale mining. This project is sponsored by USDA with pass-through funds from EPA. Term of the contract is from 1975 to 1981. An interim report will be available in the spring of 1979 and a final report in 1981.

Water Quality Hydrology Affected by Oil Shale Development

Colorado State University is under a grant from IERL-Ci to study the water quality of both surface and subsurface drainage within the oil shale areas of Colorado, Wyoming, and Utah. Specific objectives of this study are to: 1) gather all available data pertinent to the present and future assessment of the water quality hydrology in the oil shale regions of the Upper Colorado River Basin; (2) summarize and analyze these data in order to identify data deficiencies, needs for additional data, and procedures for the assessment of the impact on water quality management; and (3) develop procedures for the quantitative assessment of the quantity and quality of surface and subsurface runoff from processed shale residue and mine spoils, and to verify these procedures using existing large-scale volumetric lysimeters at Anvil Points, Colorado. Term of this project is from June 1975 to June 1980.

Vegetative Stabilization of Paraho Spent Oil Shale

Colorado State University is working under contract to IERL-Ci to study surface stability and water movement in and through Paraho spent shale and soil-covered Paraho spent shale. In addition, the distribution of water and salts in the plots was monitored with the objective of quantifying the potential salt pollution from shale residues.

This study duplicates on a small scale what might be disposal schemes for Paraho spent shale or other types of spent shale. The project involved the compaction of a 3-foot layer of Paraho spent shale over a reinforced concrete pad (132 feet long, 44 feet wide, 6 inches thick, and coated with an inert sealant). A four-inch thick layer of gravel was placed immediately over the concrete pad. This allowed collection of water which percolated through the compacted spent shale.

A layer of compacted spent shale (96 to 100 lb/ft^3) was then placed over the gravel. A layer of uncompacted spent shale was placed on top of the compacted shale and then covered with either 8, 16, or 24 inches of soil.

Two separate concrete pad units with the above treatments were constructed on Bureau of Land Management property just below the housing area of DOE's Anvil Points Oil Shale Research Facility. One unit was used to simulate a low-elevation spent shale disposal site, while the other was used to simulate a higher elevation site receiving more precipitation. Since the actual study site was located in the low-elevation zone, the high-elevation disposal zone was simulated with irrigation. The low-elevation unit was irrigated the first growing season to establish the vegetation; then left under natural precipitation. The high-elevation unit required yearly irrigation, scheduled to simulate a disposal site at 8,000 feet with 20 inches of average annual precipitation.

To develop the hydrological model phase of this study, drains were installed in the surface of the concrete pad and at the interface between the compacted and uncompacted zones. The purpose of the drains was to collect the water and salts percolating through the zones. Term of this study was from June 1975 to November 1978. A final report should be available by Summer 1979.

Vegetative Stabilization of Spent Oil Shale

Colorado State University is working under grant to IERL-Ci to continue investigations of surface stability and salt movement in spent oil shales and soil-covered spent shales after a cover of native vegetation has been established by intensive treatments and then left under natural precipitation conditions. Work under this project continues the maintenance and observations on vegetation, moisture, salinity, runoff, and sediment yields on revegetation plots established in 1974 and 1975.

The study is being performed on three different spent oil shales--coarse-textured USBM, fine-textured TOSCO II, and coarse-textured Paraho Direct mode. Various soil treatment tests are included to study plant establishment on leached spent shale, soil cover over leached spent shale, soil cover over unleached spent shale, and soil with no spent shale.

Data collected includes general observations, collection of runoff and sediment samples, soil moisture measurements, movement of salts in soil and shale profiles, maintenance of meteorological equipment, and vegetation analysis of species and groundcover. A final report is expected in 1980.

Fugitive Dust from Oil Shale Extraction

TRW, Inc., is working under contract to IERL-Ci to obtain samples of fugitive dust generated at the Paraho shale oil operations at Anvil Points, Colorado. Support services and facilities were worked out with the site operator, Development Engineering, Inc., Grand Junction, Colorado.

The nature, quantities, and specific sources of fugitive dust emissions were determined in the vicinity of mining operations and spent shale transfer points. A survey was made of the mining and oil shale handling operations to determine the sources of fugitive dust and candidate locations for collection devices. Visual observations of dust-generating operations and local wind behavior were useful in preparing the equipment plan and choice of methodology.

The principal dust collection devices were high-volume samplers. These were supplemented by cascade impaction samplers for determining particle size distribution. Testing locations and periods of operation were reviewed to obtain concurrence and assure that mining and extraction operations were not affected by the sampling activity. Meteorological instrumentation was also provided at each collection location to continuously record wind direction and velocity.

Records of mine and plant activity for each sampling site were kept by the field crew. In particular, mining activities, blasting, haul-truck operations, crushing, and shale transfer operations were logged, since all of these activities are intermittent or variable. These records were coordinated with the high-volume sampler unit records. A final report should be available in the summer of 1979.

Trace Element Analysis on Cores from the Naval Oil Shale Reserves

Lawrence Berkeley Laboratory of the University of California is examining two core samples from the Naval Oil Shale Reserve for the presence of 45 elements including As, Se, Mo, B, F, Hg, Cd, and U. One hundred and eighty-five (185) composite samples will be prepared from core segments selected to include oil shale zones under consideration for commercial development. These samples will be analyzed using the neutron activation method, Zeeman atomic absorption spectroscopy, and other selected methods. X-ray fluorescence spectrometry will be used to validate the methods previously cited in the case of selected samples. The data which results can then be used to aid in the selection of environmentally acceptable sites for in situ oil shale plants or to select zones for mining for surface retorting which would minimize environmental impacts. This project is cofunded by IERL-Ci, the U.S. Navy, and the Department of Energy. A final report should be available late in 1979.

Leaching Characteristics of Raw Surface Stored Oil Shale

Colorado State University is working under grant from IERL-Ci to determine the leaching characteristics of raw oil shale for the purpose of determining potential impacts upon water quality of large quantities of surface-stored raw oil shale. Subordinate objectives are to estimate the quantities of leachate water likely to be available in field locations and to combine these data with data on leachate concentrations to estimate potential loading of receiving waters with dissolved solids, trace elements, and organics.

Data will be obtained by subjecting columns of mined raw shale to leaching tests under a variety of flow rates, conditions of aeration, and column lengths. Chemical analyses of raw shale and effluent for common ions, trace elements, and total organics will be made. Samples of native soil will be leached under similar conditions for comparative purposes. The term of this project is from October 1978 to March 1980.

Air Emissions from Old Shale Waste Sites

Science Applications, Inc., will conduct a field testing program to determine if air emissions are being released from old in situ oil shale sites, spent shale piles or oxidation of exposed oil shale. The project entails field sampling of soils and air at ten sites of previous in situ or surface oil shale retorting activity and at one location away from any oil shale development which will serve as the control. Four soil samples and one air sample will be collected at each of the eleven sites.

Soils will be tested for SO_2, total organics, hydrocarbons, pH and soil atmosphere SO_2. Air samples will be tested for SO_2 and hydrocarbons. The term of this project is from November 1978 to September 1979.

3.3 PROCESSING

The main areas of the IERL-Ci processing program are: environmental assessment, analytical methods development, control technology development, and pollution control guidance. Eleven major projects encompass the FY 1978 research activity on oil shale processing.

Assessment of Environmental Impacts from Oil Shale Development

TRW/DRI are working under contract to IERL-Ci to study the environmental impact of oil shale development. This three-year project includes the acquisition of the necessary background data on the principal industrial shale recovery processes and U.S. shale resources, a comparative assessment of their environmental acceptability, and an evaluation of technologies available for the control of air, water, and solid waste emissions.

Work under this contract was divided into six tasks: (1) project management; (2) oil shale and recovery process characterization; (3) engineering analysis and problem definition; (4) field testing and laboratory analysis; (5) environmental evaluation, and (6) evaluation of existing environmental control technology. This project has provided a basis for establishing rational design, management, and monitoring procedures to mitigate unavoidable adverse environmental impacts prior to development of a full-scale oil shale industry.

Sampling and Analysis of the Paraho Surface Retort

A sampling and analysis research program at the Paraho oil shale retorting demonstration site at Anvil Points, Colorado, was conducted by TRW/DRI in conjunction with DOE's Laramie Energy Technology Center (LETC), Development Engineering, Inc., Grand Junction, Colorado, and EPA's IERL-Ci. The overall objective of the test program was to obtain quantitative and qualitative measurements of air, water, and solid effluent compositions, and to gain experience that will lead to improved sampling procedures and the determination of priorities for sampling and analysis of oil shale recovery operations.

The existing Anvil Points operations include two vertical retorts: a larger semi-works unit in which a portion of the off-gas was recycled and heated externally to supply heat to the retort and a smaller pilot plant in which air was introduced with recycled gas to

support combustion of carbon on retorted shale as a source of process heat. The test plan included both retorts, since their process streams (with the exception of oil product) are essentially different. Selection of sample locations was based on the need for information on process streams relative to emissions and effluents expected in a full-scale plant.

Samples taken included the recycled gases (H_2S, SO_2, NO_x, NH_3, and trace organics), recycle condensate, product oil/water, processed shale discharged from the retorts, and dust in the vicinity of crushing, screening, and conveying equipment. A variety of laboratory analysis methods were used, including wet chemical analysis, spark source mass spectrometry, high pressure liquid chromatography, thin layer chromatography, gel permeation chromatography, and gas chromatography/mass spectrometry methods (GC/MS).

Condensate water inorganic analyses were done for calcium, magnesium, sodium and potassium salts, ammonia, gross parameters, and trace elements. Condensate and product water samples were also analyzed for organic neutrals (particularly aromatics), organic acids, and organic bases. Elemental determinations of both retorted shale and raw shale particulates were made. The report from this work (EPA 600/7-78-065) was published in April 1978.

Sampling and Analysis for Retort and Combustion Gases at the Paraho Shale Oil Demonstration Plant

This second effort in the IERL-Ci environmental testing program was carried out by TRW at the Paraho shale oil demonstration plant in Anvil Points, Colorado. The test program emphasis was placed on measurements of gaseous stream constituents in recycle gas from the Paraho retort, and the combustion products from a thermal oxidizer fueled by recycle gas and auxiliary fuel. Measurements included nitrogen-based compounds (NH_3, HCN), reduced sulfur compounds (H_2S, COS, CS_2), combustion products (SO_2, NO_x, N_2, O_2, CO, CO_2), particulates, volatile trace elements (As, Hg) and hydrocarbons. Light-end hydrocarbons (C_1 - C_6) are reported for the normal alkanes, from samples analyzed in the field by gas chromatography. Heavier hydrocarbons (C_6 - C_{12}) are quantitatively reported for 53 constituents, as determined by mass spectrometer identification and gas chromatograph determination.

In that draft report of this effort (on EPA Contract No. 68-02-2560), TRW discusses comparative sampling and analysis methods, including instrumental and impinger train techniques, and their applicability to shale oil process streams is indicated. Quantitative determinations of very small arsenic concentrations were made by a GC/MS method. Possible sources of sampling and analysis error are indicated for traditional methods, especially for attempted determinations of HCN, COS and CS_2. Recommended instrumentation developments and additional analyses are indicated, as well as the applicability of the data to control technology investigations.

Environmental Characterization of In Situ Oil Shale Processing

The horizontal in situ oil shale retorting technology developed by Geokinetics, Inc., will be environmentally characterized by the IERL-Ci at the Uintah County, Utah site demonstration with the Department of Energy. Monsanto Research Corporation is under contract to EPA's IERL-Ci to provide assistance to Geokinetics personnel and Department of Energy representatives in the collection of wastewater samples and their analysis for conventional pollutants, trace metals, and priority pollutants (except pesticides). The retorting process off-gases will also be sampled and analyzed for criteria pollutants, trace elements, and specific toxic gases (HCN, NH_3, COS, CS_2 and H_2S). The final report will summarize the horizontal in situ oil shale retorting technology and process characteristics, quantify environmental impacts (emissions, effluents, and residues) and recommend future areas of environmental research.

The sampling and analysis of in situ oil shale retorting at the Laramie Energy Technology Center's (DOE) Rock Springs, Wyoming Site 12 by Monsanto Research Corporation (under contract to EPA's IERL-Ci) is designed to identify the major potential environmental problem areas from process gas emissions and water effluents. An environmental characterization will be provided by sampling and analyzing the process gas, before and after incineration, for particulate loading, particle sizes, organic material, inorganic material, total nonmethane hydrocarbons, NO_x, SO_x, COS, CS_2, H_2S, HCN, AsH_3, NH_3, O_3, CO_2, CO and moisture. The modified Method 5, Method 6, Method 7, gas chromatography/flame ionization detector and flame photometric detector (GC/FID and GC/FPD), GS/MS, inductively coupled argon plasma (ICAP), atomic absorption (AA), impinger techniques and FYRITE/ORSAT analyses will be utilized to characterize emissions. In addition, composite retort wastewater samples from each third of the burn and the total burn will be analyzed for water quality parameters, organic consent decree compounds (except pesticides), and trace elements. A stored sample of "Omega 9" wastewater (from the Site 9 burn) was provided as a background standard to be analyzed prior to initiation of the field sampling program at Site 12. This effort will complement the environmental characterization work on this process by EPA's Robert S. Kerr Environmental Research Laboratory at Ada, Oklahoma and the Laramie Energy Technology Center of the Department of Energy at Laramie, Wyoming.

Assessment of Oil Shale Retort Wastewater Treatment and Control Technology

The work and services to be performed under this FY 78 RFP (Request for Proposal) include: the definition of pollutant discharges, detailed treatability studies, and development/ testing of control technology. The award pending final negotiation is to Monsanto.

The approach will be to establish a specific list of water pollutants and their sources to provide a guideline for the assessment of line for the design of the field pilot-scale water pollution control devices to be fabricated and tested in subsequent project phases. The pollutants identified shall be those contained in oil shale retort wastewaters emanating from surface retorts and in situ retorts whose wastewaters are treated in above-ground processing equipment.

Air Pollution Investigations of Oil Shale Retorting: In Situ and Surface

Characterizing the effluent streams associated with oil shale processing is necessary from a standards and control technology standpoint. It was the consensus of the oil shale developers at a recent meeting that a commercial-size facility should be built and the environmental impact determined. The risks involved in such a venture are considerable and thus far only pilot-scale operations have been conducted. It was EPA's position that small air pollution control devices could be "slipstreamed" into some of these oil shale operations and valuable information on emissions and control technology could be obtained.

To satisfy this goal, a procurement action (RFP) was started in FY 78 in which the control of particulate, hydrocarbons, trace metals, and toxic chemicals would be evaluated from both in situ and surface retorts. The contract negotiations are in the final stages and award is anticipated in early 1979. The first year's work will consist of emissions evaluation, design, construction, and shakedown. The second and third year's work will consist of extensive field tests at in situ and surface oil shale retorts. The award pending final negotiation is to Monsanto.

Analytical Methods Manual for Oil Shale Effluents

A need was expressed to EPA by many of the personnel involved with the analytical measurement aspects of oil shale effluents to improve the reliability of the chemical methods of analysis that were applied to those effluents. To address that need, a contractual effort (RFP) was initiated in FY 78 and the award is expected in early 1979. The first year's work will involve investigating all the methods used by the oil shale chemists. Reliable methods will be separated from the others and published in report form for immediate use by these workers. Methods identified as needing additional development will be studied in the following two years with the end product being a report entitled, "Analytical Methods Manual for Oil Shale Effluents." The award pending final negotiations is to Denver Research Institute.

Overview of the Environmental Problems of Oil Shale Development

As more data becomes available and oil shale technologies are updated or modified, the potential environmental impact of the development also changes significantly. This situation was recognized by EPA when it began to study the environmental problems of oil shale under Contract No. 68-02-1811 (with TRW). One of the outputs of this contract was a document entitled, "A Preliminary Assessment of the Environmental Impacts from Oil Shale Developments." The oil shale industry has progressed in several significant areas since the publication of the first report and this new project will document, update, and/or expand that preliminary work. Most of the effort in selecting the contractor has been accomplished, and the award is expected in early 1979. The award pending final negotations is to the Denver Research Institute.

Distribution of As, Cd, Hg, Pb, Sb and Se During In Situ Oil Shale Retorting

Preliminary investigations of oil shale retorting have indicated that mercury emissions in the off-gas could be significant. The volatile properties of mercury and the other elements listed above made them candidates for additional study.

An interagency agreement with DOE's Lawrence Berkeley Laboratory was arranged to conduct a bench-scale study, and the project was initiated in October 1978. Analytical methods will be developed and tested for the measurement of each of these elements in the gas stream. Distribution coefficients for each output stream will be determined. The effect of retorting temperature and sweep gas rates on the coefficients will be used to predict similar coefficients for field operations. Sampling strategies suitable for use during large-scale field operations will be determined.

Portable Zeeman Atomic Absorption Mercury Monitor

Mercury is a toxic element which can be emitted at harmful levels from oil shale retorts. A Zeeman Atomic Absorption instrument is being constructed by the Lawrence Berkeley Laboratory which will be capable of extended field use in analyzing mercury emissions from in situ retorts.

The instrument will be scaled up from laboratory dimensions, calibrated, subjected to corrosion and performance tests, and prepared for field testing. This work will be completed in mid-1979.

3.4 ENERGY-RELATED PROCESSES AND EFFECTS

The energy-related processes and effects program is designed to identify and assess the environmental effects of each stage of an energy source's fuel cycle. The program is subdivided into four major areas: health effects, ecological effects, measurement and monitoring, and environmental transport processes. Current oil shale R&D activities for each of these areas are presented in the following sections.

3.4.1 Health Effects

EPA's Health Effects Research Laboratory, Research Triangle Park, North Carolina (HERL-RTP), and the Environmental Research Laboratory in Gulf Breeze, Florida (ERL-Gulf Breeze), are conducting research which deals with the effects of air and water pollutants associated with alternative forms of energy development on human health and on aquatic ecosystems.

Laboratory testing is being performed by both in vivo (whole animal) and in vitro (test tube) methods to identify and control hazardous agents. These projects are being conducted by Ball State University, Muncie, Indiana; Northrop Services, Huntsville, Alabama; and by UCLA. In addition, pass-through funds have been given to NIOSH; DOE's Lawrence Livermore Laboratory (LLL) in Livermore, California; the Los Alamos Scientific Laboratory (LASL) in Los Alamos, New Mexico; and to the Oak Ridge National Laboratory (ORNL), in Oak Ridge, Tennessee.

These projects are, in general, related to oil shale in that they are multi-technology oriented. The resources associated with them are not exclusively related to oil shale.

EPA's Health Effects Research Laboratory at Research Triangle Park, North Carolina, is studying the pulmonary effect of particulate material from the oil shale industry by means of intratracheal instillation of pathogen free rats and organ culture including tracheal transplants. Materials under study are shale rock direct from the Paraho mine and particulate effluent from surface retorting of shale and corresponding material from the Estonian Soviet Republic. The influence of other particles and fractions containing organic carcinogens in interaction with oil shale particulate materials are also being evaluated through in vitro systems, organ cultures, and intratracheal inoculations. Project duration is 1978 to 1981.

3.4.1.1 General Supportive Studies

Repository for Alternate Energy Source Material for Toxicity Testing

ORNL, under the sponsorship of EPA's Health Effects Research Laboratory (HERL), at Research Triangle Park, NC, provides a center for the collection, storage, and distribution of materials from new energy sources. The purpose of this EPA/ORNL function is to seek out appropriate technologies, secure suitable material for biological and chemical testing, and distribute it to a matrix of participating governmental and nongovernmental investigators. The concept is to encourage rapid testing of those effluents, products, and wastes with which there is a possibility of human contact to determine the relative risks among the various new technologies and to compare them to analogous materials from existing technologies. An additional function of the repository is to provide uniform material to investigators carrying on different test systems so that correlations may be made as to the predictive efficacy of these tests on the basis of work on the actual problems of the synthetic fuels industry.

An additional function of the repository is to carry on a continual communication between the various investigators of biological and chemical data being derived from internal and external sources.

The guidance for the project is provided by consultation with the personnel from the repository, participating biological investigators, and engineers from the various technologies.

During the past year, the repository has been concerned with developing a model approach utilizing a particular oil shale technology (Paraho) which will be studied from the aspects of community and occupational health, covering extraction of the rock, grinding, retorting, transportation of crude, refining, transportation of products, and product utilization.

Materials through the stage of refining have been logged into the repository to date and have been distributed for testing or are under consideration for distribution.

Additional commercial or near-commercial modules will be studied in a similar manner as the program continues. The project is open-ended and is funded through an interagency agreement with DOE.

3.4.1.2 Pollutant Analysis Studies

Air, Water, and Multiroute and Health Effects from Pollutants Associated with Energy Development

EPA's HERL-Ci is assessing the health effects of exposures to substances which pollute air and water as a result of energy technologies. Emphasis is being placed on potentially toxic agents resulting from fuel extraction, conversion, and combustion. The evaluation of the toxicity of the pollutants and their metabolic products includes a spectrum of bioeffect indices.

The present program includes: (1) the assessment of exposure to toxic organic chemicals which are associated with energy processes and which are waterborne. The investigations include screening for potential carcinogens, mutagens, and teratogens in water supplies, as they result from energy sources emphasizing coal and shale oil processing, and (2) toxicologic data obtained for multiroute exposures from metal pollutants resulting from fossil fuel extraction, combustion, and conservation.

Studies also include establishing additional physiological and biochemical indicators to establish a more sensitive dose; data base studies of age sensitivity and influence of dietary composition on adsorption, deposition, and toxicity of the trace elements which pollute the environment from energy-related sources; long-term effects of inhalation exposures to toxic components of fly ash, and biochemical effects of energy-related trace metals on pulmonary macromolecular metabolism. The project duration is from October 1976 to October 1977.

Chemical Fate, Detection, Metabolism and Bioaccumulation Potential of Shale Oil Components and the Effects of Marine Diesel Fuel on Marine Organisms

ERL-Gulf Breeze is studying the environmental effects of shale oil used as marine diesel fuel. There is no published literature on the effects of shale-derived marine diesel fuel on the marine environment that results from end use of the fuel, yet the U.S. Navy is planning to use it as a fuel for its ships.

Since shale-derived marine diesel fuel has not been available until March 1979, preparative experiments have been done using a surrogate petroleum-derived marine diesel. Two major categories of research have been completed: (1) studies on the potential fate and bioaccumulation in the marine food web, and (2) the effect of marine diesel on marine organisms.

The study of chemical fate, detection, metabolism, and bioaccumulation potential of shale oil components was summarized in a symposium, "Carcinogenic Polyaromatic Hydrocarbons in the Marine Environment." Papers from this symposium are being edited for publication in a book that emphasizes photochemistry, activation systems, detection methods, and bioaccumulation potential.

The second study is concerned with the effects of marine diesel fuel on marine organisms. The experimental design considered effects on planktonic settling communities, existing communities, and the resiliency of existing benthic communities. The results of these studies indicate that petroleum-derived marine diesel fuel impacts both settling communities and preexisting communities in spring and summer. Poriferan, annclidan, molluscan, and chordatan settling communities were more severely impacted than were coelenteraian and arthropodan communities. In future experiments it is important to compare the effects of shale-derived fuel with petroleum-derived fuel in order to evaluate their relative toxicities. Comparative studies would indicate whether the effects of shale-derived fuels represent a severe enough hazard to warrant special precautions for its use in the marine environment.

Denver Research Institute is studying the feasibility of the in vitro activation of microsomal drug-metabolizing enzyme systems for the development of a rapid and sensitive prescreening test. This is a test for mutagenicity of synfuel-related environmental pollutants, their derivatives, and their metabolic products which may occur on land and in aquatic and marine environments. Specifically investigated was the in vitro enhancement of biphenyl 2-hydroxylate in lepatic and plant microsomes in the presence of NADPH-regenerating septems. In addition to biphenyl, more specific substances were substituted, including various terphenyls. Because carcinogens have been reported to selectively increase biphenyl 2-hydroxylation while having no significant effect on biphenyl 4-hydroxylation and noncarcinogens do not enhance either hydroxylase, several known carcinogens and noncarcinogens have been tested. In vivo studies using the marine organism Paraunema acutum were done with the biphenyl. Biological data have been collected and analyzed for both terphenyl and biphenyl metabolism. Development of a quantitative HPLC-SPF analytical method for the separation of biphenyl, terphenyl and their hydroxy metabolites and the detection of metabolites resulting from the carcinogenic test substances has been accomplished and analyses are presently being done.

3.4.1.3 In Vivo (Whole Animal) Studies

Effect of Alternate Energy Source Material on Whole Animal Carcinogenesis by Percutaneous Application of Extracts and Fractions to Mice

DOE's ORNL is the lead laboratory for carcinogenesis for the EPA studies of the toxic

effects of products and effluents from alternative energy sources. Materials for study are derived through the chemical repository established at ORNL. Materials received are subjected to preliminary toxicity testing and fractionation followed by cancer screening by standard methods, including skin painting and injection. Data from this contract will be used to evaluate data from other methods such as bacterial mutagenesis, neoplastic transformation, intratracheal instillation, etc., to arrive to a comprehensive view of the relative value of various methods in dealing with a practicable evaluation of the carcinogenic potential of crude material. This project is under the sponsorship of EPA's HERL-RTP and IERL-RTP. Project duration is from September 1976 to September 1978.

Morphological Variants in Damaged Sperm

Lawrence Livermore Laboratories (LLL), under sponsorship of the Interagency Agreement is conducting this project. Ionizing radiation as well as various mutagens, carcinogens, and teratogens are known to induce elevated levels of morphologically abnormal sperm in mice. The objectives of this study are: (1) to develop further and apply the detection of morphologically abnormal mouse sperm as a rapid, simple, quantitative assay of the pathology response of the male gonad to toxic agents; (2) to extend the studies in the mouse to the hamster; and (3) to develop the methodology of automated scoring of abnormally shaped sperm, especially after the exposure of the male to toxic agents. Of special interest are possible effects of the chemical pollutants associated with the recovery, process stream, and emission of nonnuclear sources of energy, especially coal gasification and oil shale extraction in situ.

To accomplish these objectives, groups of test mice have received subacute or chronic exposures by injection, inhalation, or dermal application. The percent of abnormally shaped apididymal sperm will be determined as a function of dosage and time after exposure. These results will be compared to those obtained by more conventional mutagens, carcinogens, and teratogens. Preliminary studies with the hamster and mouse have shown that these two species are qualitatively similar in response. Furthermore, an attempt is being made to distinguish sperm morphology in these species based on suggested differences in fluorescent dye uptake. These results may lead to automated analyses of sperm morphology. Project duration is from June 1975 to June 1980.

Detection of Early Changes in Lung Cell Cytology by Flow Systems Analysis Techniques

LASL is studying the application of modern automated cytology techniques for assessing damage to humans resulting from exposure to physical and chemical agents associated with oil shale and coal extraction, conversion, and utilization. The approach is to apply unique flow-system cell-analysis and sorting technologies developed at LASL to determine cytological and biochemical indicators of early atypical changes in exposed lung epithelium using the Syrian hamster initially as a model test system.

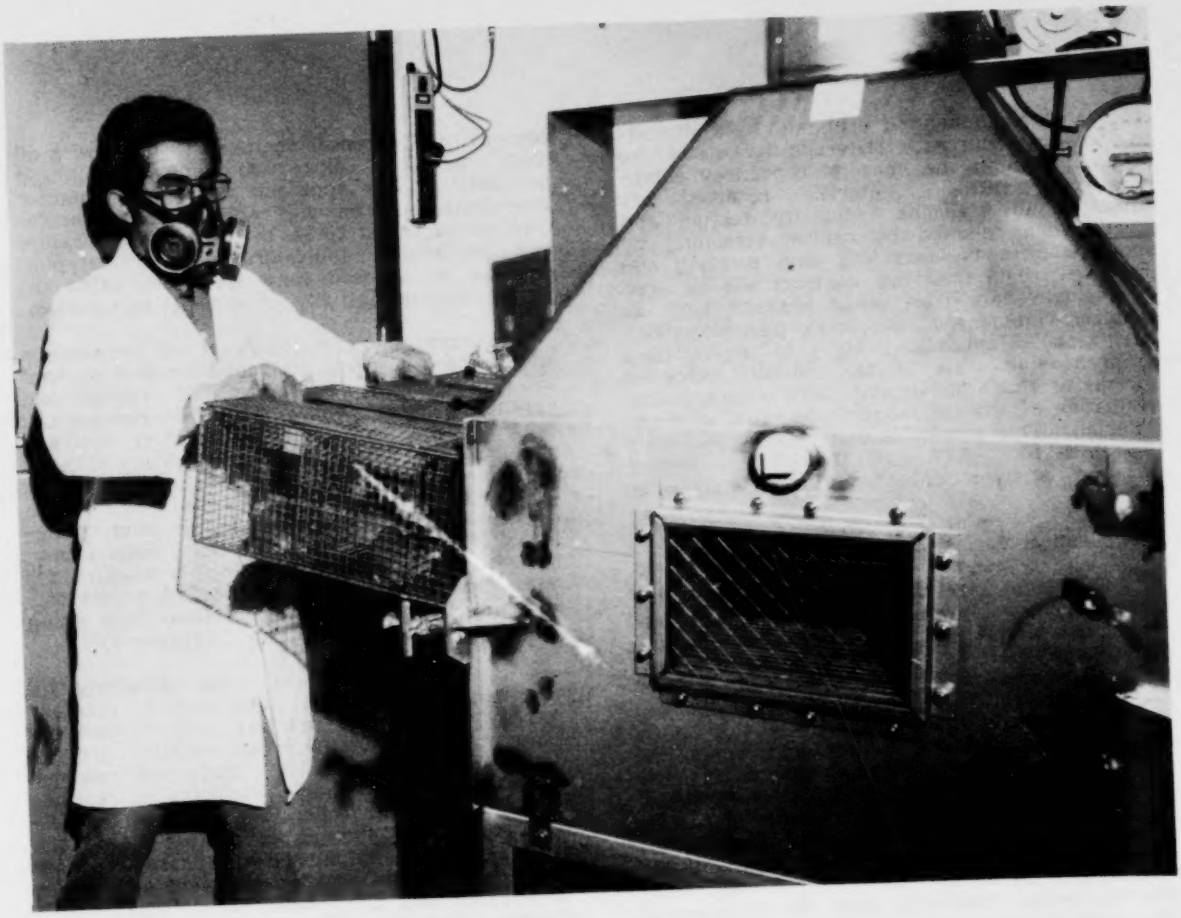
Current plans are to adapt cell preparation and staining methods developed for flow systems to characterize lung cells from normal and exposed hamsters using the multiparameter cell separator and multiangle light-scatter systems. This includes acquisition of respiratory cells by lavaging the lungs with saline, adapting cytological techniques developed on human gynecological specimens to hamster lung epithelium for obtaining single-cell suspensions, utilization of existing staining techniques for measurement of cellular biochemical properties, and initial characterization of lung cells using flow analysis instrumentation. (Figure 6)

LASL has achieved some progress in measuring DNA content, total protein, esterase activity, cell size, nuclear and cytoplasmic diameters, and multiangle light-scatter properties of exfoliated hamster lung cell samples composed of macrophages, leukocytes, epithelial, and columnar cells. As this new technology is adapted further to analyze lung cells from hamsters and subsequent characterization studies are completed, measurement of changes in physical and biochemical cell properties as a function of exposure to toxic agents associated with synthetic fuels energy production will be performed, with the eventual examination of sputum samples from occupationally exposed humans. This project is being sponsored by DOE with EPA pass-through funds. Term of this project is from 1976 and is continuing.

Mortality, Morbidity, and Industrial Hygiene Study of Oil Shale Workers

NIOSH is studying 320 men who have worked in pilot oil shale operations. The men are divided into three groups consisting of workers from: (1) the U.S. Bureau of Mines; (2) the Joint Venture of the Colorado School of Mines Research Institute, Anvil Points, Colorado; and (3) the Union Oil Retort facility in Grand Valley, Colorado.

A retrospective mortality study of approximately 60 men will be done in-house while a cross-sectional morbidity examination to evaluate several morbidity aspects that may be associated with oil shale occupations will be done by contract. Mortality due to 21 specific causes will be determined after an extensive follow-up effort, and the death certificates of those who have died will be examined. The various causes of death will be examined to determine if an excessive number of deaths were due to a particular cause. Numerous indices of health



(Photo courtesy of L.M. Holland, Health Division, LASL)

Figure 6.

TESTING THE EFFECTS OF SHALE DUST ON ANIMALS

Hamsters are being placed into an inhalation chamber during a chronic inhalation study of shale dust.

regarding the living men will be assessed through physical examinations and health questionnaires. NIOSH has contacted various people knowledgeable in oil shale technology, as well as others who are or have been involved in health studies related to oil shale mining and retorting.

An additional contract was signed by NIOSH with Utah Biomedical Testing Laboratory, Salt Lake City, to conduct testing on cancer of the bladder and respiratory system. NIOSH's efforts are supported by EPA pass-through funds. Term of the contract was from November 1976 to November 1978.

Determination of the Influence of Mineral Cofactors in Conjunction with Carcinogens from Energy-Related Materials

Northrop Services, Huntsville, Alabama, was under contract to the EPA's HERL-RTP to determine the influence of environmental materials such as fibrous amphiboles, fine particles, etc., as cofactors with carcinogenic influences from alternative energy sources such as coal gasification and liquefaction, and shale oil products and effluents. Intratracheal instillation and intrapleural inoculation were used, and the end points would have been the formation of cancer in the lung or pleura or the development of precancerous lesions compared to appropriate controls. The duration of this project was from December 1975 to August 1978.

In Vivo Screening for Gene Mutation in Mouse Germ and Somatic Cells

DOE's ORNL is conducting this study with EPA pass-through funds. In screening for mutagenic agents it is important to include mammalian tests for gene mutations. In this project, identification of mutagens associated with coal and oil shale technologies that can induce gene mutations and small deficiencies will be accomplished by scoring for: (1) transmitted specific-locus mutations induced in germ cells, and (2) somatic mutations in coat color genes.

The specific-locus method developed has been used extensively in radiation work and has already proved its usefulness in chemical mutagenesis studies. It is the only established, reliable, and definitive test for transmitted gene mutations and small deficiencies currently available in mammals. To make the method economically efficient for screening purposes, it will be used to test whether there is anything mutagenic in a whole mixture of compounds, for example, in an effluent. One mixture from a coal conversion process that has just become available after studies with nonmammalian systems is now being used in preliminary toxicity tests. An in vivo somatic-mutation method, developed in an earlier X-ray experiment, has now been explored for its usefulness in the prescreening for germinal point mutations induced by chemicals. In an array of seven compounds tested, parallelism with spermatogonial specific-locus mutation rates was found, indicating that the in vivo somatic-mutation test may detect point mutations in addition to other types of genetic changes that lead to expression of the recessive. The method is now being used to test fractions from coal conversion processes. Term of this contract is from 1976 and is continuing.

The Carcinogenic Effects of Petroleum Hydrocarbons on Selected Marine Estuarine Organisms

It is well documented that epidermal papillomas occur in several flatfish species along the West Coast of the U.S., in incidences exceeding 50 percent in selected groups of young fish. The possible involvement of polycyclic aromatic hydrocarbons in papilloma development has been suggested, but never proven.

If chemicals such as benzo(a)pyrene are responsible (either directly or indirectly) for the appearance of neoplasia in aquatic species then these animals have potential as early warning indicator systems for human carcinogens and mutagens in the aquatic environment. This program attempts to identify pathological alterations in internal organs, as well as externally, in response to benzo(a)pyrene exposure. It is also testing exposure effects on the induction of hepatic and extrahepatic benzo(a) pyrene hydroxylase activities in a flatfish.

The period of the program was December 1976 through December 1978. It was being performed by the University of Washington, Seattle, Washington, for NIEHS-RTP.

3.4.1.4 In Vitro Studies

Determination of the Effects of Material from Alternate Energy Sources on Upper Respiratory Tract Clearance Mechanisms

Ball State University, Muncie, Indiana, under sponsorship to EPA's HERL-RTP, is screening a variety of substances for their toxic effect on mucociliary activity using an in vitro model system. Since cilia play a significant role in pulmonary clearance, proper functioning is essential for defense against various environmental insults. However, ozone, nitrogen dioxide, nickel, and cadmium have an adverse effect on this system. Therefore, it becomes increasingly important to determine if alternative energy sources such as shale oil and coal gasification and liquefaction, or particulate effluents from power stations, stationary engines or mobile sources produce pollutants toxic to the mucociliary escalator.

Consequently, isolated hamster tracheal rings are exposed to pollutants in vitro.

Parameters measured are the: (1) effect on ciliary beat frequency; (2) effect on the energy source (ATP) of beating; (3) effect on ciliary and tracheal morphology, and (4) recovery of the tracheal rings after exposure. In all cases, parameters are tested for dose-response effects. Project duration is from October 1975 to May 1979.

Quantitative Mutagenesis Testing in Mammalian Cellular Systems

Lawrence Livermore Laboratory is to develop and apply quantitative and multiple-marker assays utilizing cultured mammalian cells to evaluate the potential mutagenic effects of agents derived from energy technologies. Additionally, LLL will use these existing and newly-developed biological screening systems to identify mutagenic agents associated with coal and oil shale extraction, conversion, or utilization.

This program proposes the use of multiple drug-resistance markers for forward mutation in cultured Chinese hamster ovary (CHO) cells, as well as in vitro and host-mediated in vivo/in vitro procedures in the Syrian hamster embryo (SHE) system. The markers being developed measure the frequency of forward mutation at the recessive azadenine-resistant marker, the X-linked azaguanine-resistant phenotype, and the dominant ouabain-resistant locus. Established procaryote and lower eucaryote systems will be used for comparison and reference; the most satisfactory markers in all systems will then be combined into a standard protocol in which each of the gene loci can be measured for mutation following exposure to a particular test agent or combination.

To date, both CHO and SHE systems have been tested with the standard mutagen EMS, and experiments using specific hydrocarbons relevant to energy technology are now underway. This project is being sponsored by DOE under pass-through funds from EPA. Project duration is from June 1975 to June 1980.

Development of Cytochemical Markers for Cell Transformation and Carcinogenesis

LLL is developing rapid, sensitive, and economical systems for the in vitro and cytological assay for carcinogenic effects of substances involved in the extraction, conversion, and utilization of nonnuclear energy sources, with particular consideration of in situ coal gasification, shale oil utilization, coal burning power plants, and geothermal power plants. The approach is based on the development of cytochemical markers for cell transformation, and on the ability to quantify such markers by microfluorometry and by flow system analysis and sorting.

There are two phases to this work: (1) the development of appropriate test systems whose response is defined by well characterized and representative carcinogenic agents, and (2) the application of such systems to substances released by energy technologies, and including testing with whole and fractionated samples of effluents. This project is under the sponsorship of DOE with pass-through funds from EPA. Project duration is from June 1975 to June 1980.

Somatic Cell Genetics

LASL sponsors a genetics program which is isolating temperature sensitive mutants (variants) of the mammalian cell for use in studying the genetics of cell life-cycle traverse. In addition to these mutants, several auxotrophic clones have been isolated and a mutation system has been developed for use in assessing the mutagenicity of suspected carcinogens derived primarily from coal gasification and oil shale extraction processes. The Ames Salmonella/microsome test system will serve as an ancilliary test for mutagenicity. The mammalian cell forward and reverse mutation system and the Ames bacterial test system currently are functional in this laboratory. Temperature-sensitive life-cycle traverse mutants are being analyzed to determine in what phase of the life-cycle the ts phenotype is expressed using the LASL flow microfluorometer. This project is sponsored by DOE under pass-through funds from EPA. This was a two-year program ending in 1977.

Analysis of the Effects of Energy-Related Toxic Materials to Karotype Stability in Mammalian Cells

LASL is developing systems for the rapid detection of karyotypic changes in mammalian cells as a result of exposure to energy-related environmental pollutants and to screen selected subjects utilizing these systems. Flow microfluorometry (FMF) of isolated, fluorescently stained chromosomes will be used to identify chromosome aberrations, and FMF of stained intact cells will be used to detect mitotic nondisjunction. Cadmium will be used as the clastogenic agent in the development of a test system. It has been demonstrated that chromosome analysis can be accomplished by flow systems in mammalian cells with relatively simple karyotypes. Cadmium at low concentrations is a potent clastogen. It induces primarily chromotid-type aberrations.

LASL has also demonstrated that tolerance to the damaging effects of cadmium can be induced in fibroblast cells in culture by long-term exposure of the cells to sublethal concentrations of cadmium. There are plans to repeat these experiments on human fibroblast and

lymphocyte cells in vitro and to extend these studies to other toxic agents associated with alternative energy technologies. This project is being sponsored by DOE with EPA pass-through funds. Term of the contract is from 1976 and is continuing.

Effects of Products of Coal and Oil Shale Conversion on Cell Cycle Kinetics and Chromatin Structure.

LASL is providing a means for detecting and monitoring damage to humans as a result of exposure to various toxic chemical and physical agents. To obtain an idea of the parameters to be monitored in humans, it is first necessary to establish the effects of agents on cells in simpler model systems.

Earlier experience with drugs which act as carcinogens and teratogens has convinced researchers that changes in population cell-cycle distribution and alterations in chromatin structure may provide useful early indicators of sublethal damage to cells exposed to hazardous agents. Examination will be made of alterations in these parameters following exposure to specific energy-related toxic substances in currently available tissue-culture systems which show promise as a predictive indicator of response to humans. A technique has been developed that allows preparation of both cycling and noncycling cell populations in tissue-culture, mimicking these classes of somatic cells in humans. By combining autoradiography, cell number enumeration, and flow microfluorometry, it will be possible to obtain highly detailed information regarding the cellular kinetics response of both arrested and cycling populations to treatment with toxic agents.

Results obtained to date suggest that DNA interactive agents elicit different types of kinetics responses in treated cells, indicating a degree of specificity of interaction between various alkylating and intercalating agents and the genome. This project is sponsored by DOE with EPA pass-through funds. Term of the contract is from 1976 and is continuing.

Mutagenicity Assay of Fractionated Coal Conversion and Shale Oil In Situ Retorting Products

ORNL is monitoring environmentally important processes for genetic damage using rapid screening assays to identify mutagenic agents. They have extended in initial work on the crude product from a coal liquefaction (Syncrude/COED) to subfractionation and have identified the potential genetic hazards with the Ames system. The most active fractions appear to be the neutrals and the basic (Ether soluble) components prepared by liquid extraction procedures. Parallel identification work by the analytical chemistry division has been carried out and a selected group of polycyclic compounds involved has been assayed and evaluated for mutagenicity. The crude product assays have been extended to the separator liquor components of the same process, again using the coupled analytical-biological assay approach.

Similarly, parallel studies with fractionated materials have been initiated with the Synthoil Process (liquefaction), the Synthane Process (gasification), and the Shale Oil In Situ Retorting Process. Primary fractions of various steps or materials from these processes have been prepared and assayed for potential genetic damage.

The mutagenicity of crude industrial products and effluents was arrayed with the Salmonella/microsomal activation system. Test materials (crude products from coal conversion processes and natural crude oils) were initially fractionated into primary classes by liquid--liquid extraction and then further fractionated by column chromatography. Prescreening was accomplished over a wide concentration range with the Ames tester strains. Active fractions (mainly the neutral fractions containing polycyclic aromatic hydrocarbons and certain basic fractions) can be identified, and dose-response relationships can be established. Standard values are expressed as revertants per milligram of the test material assayed with frame-shift strain TA98 including metabolic activation with rat liver preparations. Total mutagenic activity of synthetic fuel samples was consistently higher than that of natural crude "controls." Activities of subfractions are roughly additive and presumably reflect the mutagenic potential of the whole test material. These results are being extended to other genetic assays. Chemical identification is carried out along with the bioassays.

The application of short-term mutagen tests was evaluated using bacterial, fungal, mammalian cells and Drosophila on synfuel A fraction. The results of the use of these systems simply show that-biological testing and genetic assays, in this case, can be carried out with the developed tester systems, but only when coupled with the appropriate analytical separation scheme.

The Quantitative Evaluation of Hazardous Chemicals Using a Closed Aquatic Test System

Brookhaven National Laboratory is developing a new comparative test system, using clones of fish P. formonsa, capable of detecting the carcinogenicity of chemicals by treatment of cells in vitro or by treatment of whole animals.

The approach is to treat cells in vitro with presumptive carcinogen by (1) injecting cells into fish and scoring recipient fish for tumors one or two years later, or (2) introducing

presumptive carcinogen directly into the water tank to assess their effects on the whole animal. This is a continuing program that began in 1976.

The Interaction of Chemical Agents Present in Oil Shale with Biological Systems

The objectives of this NIEHS project are: (1) to study the role of free radical intermediates formed during the metabolism of polynuclear hydrocarbons in the toxicity of these agents, (2) to study the mechanisms by which UV and visible light synergizes the tumorgencity of polynuclear hydrocarbons on skin, and (3) to study the binding of heavy metal ions to plasma and tissue proteins on the body distribution of the metal ions.

The formation and characterization of free radical intermediates will be done using electron spin resonance (ESR) spectroscopy. ESR spectroscopy can detect unpaired electrons present both in free radicals (organic or inorganic) and in paramagnetic metals. In some cases, spin trapping techniques will be used to transform reactive free radical intermediates to form stable radicals which can then be identified.

Development of Permanent Epithelial Cell Lines

DOE's ORNL is conducting this study with EPA pass-through funds. Objectives are: (1) To develop the means by which chemicals associated with nonnuclear energy generation, especially agents arising from coal and oil shale extraction, can be screened for potential carcinogenic activity. Reliability, speed, and cost relative to current animal exposure techniques, are emphasized. (2) To utilize appropriate cultured cells developed under the first objective to study hydrocarbon metabolism into carcinogenically active forms, and determine the mechanism of chemical carcinogenesis.

A research group with two discrete but closely related approaches to these problems is being developed. The approaches are: (1) cell biology--the major focus here will be the development of permanent cell lines of epithelial origin (human, when possible and appropriate) which possess the enzymatic equipment for carcinogen activation and which are trans formable with high frequency, and (2) biochemistry--principal focus will be the study of the metabolism of polycyclic hydrocarbons in various cell lines developed in the first approach to establish with certainty the "ultimate" carcinogenic metabolite, using primarily high pressure liquid chromatography techniques. This contract was initiated in 1976 and is continuing.

Development of an In Vitro Assay for Cocarcinogenesis of Coal/Oil Shale Derivatives

The UCLA School of Medicine is developing an in vitro assay capable of detecting the cocarcinogenic potential (with X-rays) of materials produced during coal and oil shale processing. Initially it was proposed to utilize mouse tissue cultured cells and an already established transformation assay. Initial experiments indicated that rodent cells may possess lesions induced by alkylating agents different from human cells and that their use as screening materials might be misleading. This was shown by demonstrating that a variety of DNA damaging agents yielded significantly different effects on various cell lines when measured by a variety of techniques.

It was hypothesized that a ventral difference between the lines (rodent versus human) may be the "activation of on-cogenesis" related to the strand breakage induced, and because rodent lines carry transforming virus materials of a complete or incomplete nature, which is lacking in most human target cells. This is being evaluated through cell hybridization analysis using hybrids made by sendaivirus fusion of cells lacking either: (1) different DNA repair enzymes, or (2) (potential) RNA viruses. This project is sponsored by DOE with EPA pass-through funds. This contract began in 1979 and is continuing.

3.4.2 Ecological Effects

The Environmental Research Laboratory in Duluth (ERL-Duluth) is providing predictive information with regard to potential toxicants to the aquatic environment resulting from coal and oil shale extraction and conversion. Current work involves chemical characterization and bioassays of retort process waters and chemical and analytical studies of water in the Piceance Creek basin. Term of the present projects is 1975 - 1980.

3.4.3 Measurement and Monitoring

Projects under the measurement and monitoring program deal with air, surface, and groundwater monitoring and methodology development, instrumentation development, and identification of wastes and effluents. Work is being conducted by EPA's Environmental Monitoring and Support Laboratory in Las Vegas (EMSL-LV), the Region VIII office in Denver, the Environmental Research Laboratory in Athens (ERL-Athens), USGS, DOE, and NBS.

3.4.3.1 Air Monitoring

Oil Shale Area Meteorological Data Analysis

CDM Limnetics, Wheat Ridge, Colorado, has purchased upper air meteorological data from the National Climatic Center in Asheville, North Carolina, for the National Weather Station at Grand Junction, Colorado. The temperature, wind speed, and wind direction data collected at Grand Junction, Colorado has been compared with like data obtained near the Colorado federal oil shale lease tracts. A determination

of the representativeness of obtaining upper air data for 15 days in the central portion of each quarter has been made. A report providing this low level radiosonde monitoring data comparison has been released. This completed project was sponsored by EPA, Region VIII, Denver, Colorado.

Air Quality and Surface Wind Monitoring in Colorado

The Colorado Department of Health is under contract to EPA Region VIII to install and operate air monitoring sites in selected areas of western Colorado to collect baseline data prior to major expansion of energy activities. Particulate samples from the energy area are analyzed for nitrate and sulfate content. EPA Region VIII is administering this project with OEMI funds. Term of the contract is from 1975 to 1980. Annual reports were published in January 1979.

Upper Air Meteorological Data Collection

Aeromet, Inc., Norman, Oklahoma, has collected upper air data at tract U-a/U-b from June 1, 1976 through October 30, 1977, and at tract C-b from June 1, 1976 through November 30, 1978. Temperature, wind speed, and direction versus altitude were measured via pilot balloons and temperature sondes. Single vs double theodolite evaluations were made. Temperature and wind data were used to generate stability-wind rise data on a seasonal, annual, and monthly basis. These data also provided mixing height data. Similar data collection will begin at C-a in 1979. EPA Region VIII is administering this project with OEMI funding. Term of the contract is from 1976 to 1980.

Visibility Monitoring in Piceance Basin

Instrumentation has been provided by EPA Region VIII to leasees of Tract C-b for measurement of visibility. A comprehensive basin-wide program is contemplated for commencement in 1979. EPA Region VIII funds total about $50,000 for this project.

3.4.3.2 Water Monitoring

Monitoring the Impacts of Oil Shale Extraction on Groundwater Quality

This project was initiated in late 1976 with the goal of developing guidelines for the design of groundwater quality monitoring programs for western oil shale operations. The initial focus of the study was the deep subsurface retorting type of operation proposed for Federal Oil Shale Lease Tracts U-a and U-b in eastern Utah. The study format follows a generic groundwater quality monitoring methodology developed under previous contract by General Electric-TEMPO for EPA. This structured monitoring evaluation process includes:

- identification and characterization of potential sources of groundwater quality impact
- characterization of the location of these sources with regard to hydrogeology and existing groundwater quality
- assessment of mobility and attenuation of potential pollutants in the subsurface
- development of a priority ranking of potential sources of impact and of potential pollutants.

An initial pass through this design sequence has been completed using the proposed Utah oil shale operations as a case study. A priority ranking of potential pollution sources and constituents associated with those sources has been developed (Slawson, G. C., 1979, Groundwater Quality Monitoring of Western Oil Shale Development: Identification and Priority Ranking of Potential Pollution Sources, EPA-600/7-79-039). The second monitoring design report (Slawson, G. C., 1979 [draft], Groundwater Quality Monitoring of Western Oil Shale Development: Monitoring Program Development, FE78TMP-90) is in review by EPA.

In support of this project, a summary of research and development related to oil shale operations has been completed (Slawson, G. C., and Yen, T. F., 1979, Compendium Reports on Oil Shale Technology, EPA-600/7-79-039) in cooperation with the University of Southern California. Topics considered are mining, retorting, shale oil upgrading, organic and inorganic characteristics of oil shale products, and potential environmental controls on the oil shale industry.

Contributors to this contract include TEMPO's Water Resources Program, University of Southern California, Denver Research Institute, and several prominent consultants in the field of hydrology and groundwater pollution (Dr. D. K. Todd, Dr. D. L. Warner, Dr. K. D. Schmidt, Dr. L. G. Wilson).

Legal entanglements related to ownership of Tracts U-a and U-b have delayed those development operations. Modified in situ developments proposed (and now under construction) on Colorado Tracts C-a and C-b represent the present focal point for commercial development of oil shale. Hence the project has shifted emphasis in its assessments from the Utah to the Colorado operations. Much of the information gained in the Utah studies is transferable to the associated surface operations on the Colorado tracts. The major new area of study is, of course, the modified in situ retorts and the potential for groundwater quality impact

after abandonment. A preliminary assessment and monitoring design report will be prepared in late spring 1979. This design will include identification of data deficiencies and uncertainties associated with monitoring of the proposed development operations and recommendations for field and possibly laboratory studies needed to address these deficiencies.

The results of this testing and analysis phase, to be initiated in late spring 1979, will be used to finalize recommendations for groundwater quality monitoring of surface and modified in situ oil shale operations. This guideline document will provide technical information and a planning format for the design of monitoring programs. The study results may be used by industrial developers and their consultants as well as by the various local, state, and federal agencies with responsibilities in environmental monitoring and planning.

Energy-Related Water Monitoring Data Integration

EMSL-LV is establishing a water monitoring network throughout the western U.S. to monitor and assess the impact of energy resource development. Through the use of computer data banks, water monitoring stations that are currently in operation, and those prior to 1970 which have reported a large number of measured parameters were selected for incorporation into a primary monitoring network. Parameters of interest were identified and a quality assurance program is being established in participating laboratories. Data from the primary network stations are being augmented with data from other stations. An assessment of baseline water quality, trends, and impacts on a basin-by-basin basis is underway. Data gaps and monitoring problem areas are being identified, and actions will be taken to correct them. The primary network will be updated periodically and extended into areas not presently addressed. Monitoring methodologies and parameters of interest are being assessed and improvements recommended. Term of the contract is from 1975 to 1980.

Water Quality and Geochemistry of Shallow Aquifers of Piceance Creek, Colorado

The objective of the USGS program is to define the variation of water chemistry in the aquifers of the Piceance basin and its relationship to the soluble minerals of the Green River Formation. A digital model of the chemical reactions will be developed and coupled with the existing digital model of the aquifer hydraulics and used to predict the effects of oil shale mine dewatering on water chemistry.

Water quality samples will be collected and analyzed from the wells drilled in the basin. Samples will also be collected from springs. A digital model of the water chemistry will be developed and coupled with the existing groundwater hydraulics model. The chemical data will be used to calibrate the model. Mine dewatering operations can then be simulated to predict changes in the water chemistry of the mine discharge.

The project began in July 1974. The initial interpretive phase of the project was completed September 1978. Monitoring of groundwater quality has been in progress since 1974 and will continue throughout the period of oil shale development on the prototype lease tracts. In 1976, a two-layer two-dimensional solute transport model of the groundwater basin was constructed but could not be properly calibrated. The invalid assumption was that the basin is primarily a two-aquifer system with water quality differences between each aquifer but not within each aquifer. It now appears that significant concentration changes may occur with depth within the aquifers and that high concentration water in some wells and springs is a composite mixture of water of greatly different quality rather than a representative sample of water quality in the aquifer as a whole. In order to consider the effects of the concentration variation with depth in the aquifers, a three-dimensional solute transport model of the basin was constructed.

Continued work in 1977 with the finite element solute transport model has shown that the program could successfully solve the flow equation representing the Piceance basin but could not solve the corresponding solute transport equations. As a result, this finite difference solute transport model was constructed and successfully calibrated in 1978, using equilibrium groundwater flow and dissolved solids concentration data.

The model has been used to simulate the effects of mine dewatering and resaturation on the groundwater quality in the basin. Simulation results indicate that enhanced vertical movement of groundwater near pumping mines in Tracts C-a and C-b will produce a zone of better quality groundwater in the deeper aquifers adjacent to each mine. The effects of spent oil shale leachate in an abandoned and resaturated mine in both tracts was also simulated. Results indicate that a large zone of degraded groundwater quality will occur downgradient of Tract C-a, while only a small zone occurs near Tract C-b. The proximity of Piceance Creek to the C-b mine causes groundwater of degraded quality to move into the stream without affecting large areas of the surrounding aquifer. A report, "Hydrochemistry and Simulated Solute Transport in Piceance Basin, Northwestern Colorado," documenting the results of this investigation has been prepared for open file release and publication as a U.S. Geological Survey professional paper. Subject to approval, the report will be released in the summer of 1979.

Water Quality Monitoring on White River, Parachute Creek and Logan Wash in Oil Shale Areas of Western Colorado

The objective is to inventory the water resources and describe the hydrologic system of Parachute and Roan Creeks.

Basic water data will be collected on streamflow, sediment yields, water quality, spring discharge, and groundwater potentiometric levels. The data will be used to document the existing hydrologic conditions in Parachute Creek and Roan Creek. The data will provide a description of the relationship between surface water and groundwater quantity and quality in the study area.

The project began in July 1974 and is planned to continue through September 1980. Four continuous record surface water stations and one miscellaneous station were operated in the study area at the start of 1976. Two of these stations are equipped with automatic suspended sediment samplers and two-parameter water quality monitors. Water quality samples are collected monthly at three sites, and sediment samples are collected monthly at one site. In addition, twelve surface water stations are operated by industry. Records from these stations have been made available to the U.S. Geological Survey. Later in 1976, Occidental Oil Shale, Inc., gave permission for the use of three alluvial wells in major drainages around its in situ operation. Water levels and water quality samples are being obtained from these wells. A deep core hole near Mount Callahan was also provided by Occidental, permitting water levels and water quality samples to be obtained in the upper and lower aquifers of the Green River formation.

By 1977, a new project in the Parachute Creek basin was funded by the U.S. Navy; the objective is to inventory the water resources and describe the hydrologic system of the U.S. Naval Oil Shale Reserve No. 1. Five surface water gauges, two automatic sediment samplers, three precipitation gauges, and one climate station have been installed on the Reserve. Data from this project will be used to supplement the existing program for Parachute and Roan Creeks.

Monitoring of surface water and groundwater quality is continuing in 1979. Eight surface water gauging stations, four automatic sampling sediment stations, five two-parameter monitoring stations are maintained by USGS. Ten surface water stations are maintained by private oil companies. Ten deep core holes have been drilled and hydrologic information collected on the Naval Oil Shale Reserve. Four private oil company core holes have been reworked for hydrologic monitoring. Two production wells and ten observation holes have been installed for alluvial aquifer testing in the Roan Creek basin. Water quality samples of miscellaneous sites were collected for 35 springs and surface water sites near existing oil shale operations. A final report on the investigation is planned for 1980 as a professional paper.

Collection of Geochemical Data in the Piceance Creek Structural Basin of Colorado

The USGS, Lakewood, Colorado, monitored the collection and analysis of geochemical data on the relatively shallow groundwaters that may be impacted by the extraction of oil shale in the Piceance and Yellow Creek basins of Colorado. Water samples were collected from approximately 12 wells and many springs. Chemical analyses for approximately 30 parameters were collected on selected samples. Data will be used to refine predictive models of resultant water quality both for those waters encountered by mining operations and waters centering surface drainages, springs, and seeps. USGS was funded by EPA pass-through funds. Term of the contract was from 1976 to 1978.

Definition of Potentiometric Surface of Shallow Aquifers in Piceance Creek Impacted by Oil Shale

The objective of this study is to supplement the Geological Survey effort required to describe the detailed steady state conditions of the groundwater system of the Piceance Creek basin prior to mining oil shale. The unstressed potentiometric surface will be defined in order to calibrate digital models that can then be used to predict the impact of oil shale extraction, waste disposal, and water storage reservoirs on the shallow ground and surface water regimes. The digital model will also incorporate chemical and water quality data to provide predictions of changes in the shallow groundwater and surface water regimes that could be brought about by additional oil shale extraction in the Piceance basin.

The total project will involve the drilling of 40 wells, 20 completed in the upper aquifer and 20 completed in the lower aquifer, in the Piceance and Yellow Creek drainages of the Piceance basin. The wells will be of adequate diameter to accept submersible pumps for aquifer testing and water quality sampling. Water levels will be monitored on a quarterly basis and correlated with continuous hydrographs already installed at seven locations in the basin. The data collected will be used to construct potentiometric maps for the aquifers which will be used to improve the calibration of the groundwater model and to provide baseline data for the region. The data so collected will be supplemented by similar data from the lease tracts and from wells where completion statistics and methods are known. In addition to U.S. Geological Survey and Bureau of Land Management funding, the U.S. Environmental Protection Agency is providing funds for collection of

basic data to be used as input to the digital model.

The project began in July 1974. The observation well drilling contract was completed in January 1976, and consisted of the drilling of 22 observation wells. The total footage drilled was 25,092 feet. By September 1976, water levels in 58 wells were being measured as part of the semiannual measurement program and geophysical logging of 24 observation wells drilled during 1976 was completed. In addition, seven digital water level recorders were in operation. The semiannual mass measurement of wells by helicopter has been conducted through 1978.

A basic data report describing the hydrologic information, released under the title "Digital Model of Groundwater Flow in the Piceance Basin, Rio Blanco and Garfield Counties, Colorado, Water Resources Investigations 78-46," includes the results of these studies and the resulting three-dimensional groundwater flow multiaquifer model thus developed. The model uses the iterative, alternating direction implicit procedure to solve the finite difference flow equations. The digital model is documented by a program listing and flow charts. Data used in the model and sample output are presented to demonstrate the simulation of steady state flow in the aquifer system.

Water Quality Monitoring Techniques Evaluation

Water quality monitoring techniques and procedures were tested in the lower reaches of the White River adjacent to tracts U-a/U-b and their utility for application in such areas was evaluated. Conventional grab sampling procedures, automated in situ pump-type samples, electronic contact sensors, and various biological sampling methods were included in the study. Preparation of a final project report is currently underway. Term of the project is from 1975 to 1979.

Assessment of Macroinvertebrate Monitoring Techniques

Three methods of macroinvertebrate collection were evaluated for selectivity, reproducibility, capture effectiveness, and cost efficiency in the White River near Meeker, Colorado. Samples were collected with a standard Surber sampler, with a portable invertebrate box sampler (PIBS), and with the Standardized Traveling Kick Method (STKM). The methods were evaluated in riffles of the White River directly upstream and downstream from the confluence of Piceance Creek, as well as at a comparable riffle at an upstream control station. The data are evaluated in a report which is expected to be published by April 1979. Term of the project was 1977 to 1978.

3.4.3.3 Instrumentation Development

Instrumentation and Methods for Characterizing Aqueous Effluents from Oil Shale

At ORNL, DOE is studying the feasibility of large-scale oil shale processing in the Green River Formation. Plans include surveillance of related effluents. This project focuses on the development of methods for the chemical characterization of aqueous effluents associated with retorting processes. Attention is being given principally to organic and trace metal components. Organic components are being analyzed by several methods under development. Major organic components are analyzed directly by gas chromatography with no sample pretreatment. Minor and trace organic components are removed from the samples by adsorption on activated carbon, neutral macroreticular resins, and ion exchange resins. The components are profiled by gas chromatographic methods employing standard and specific element detectors. Fractionation of the organic mixture is followed by identification and quantification of some nitrogenous bases. Trace metals will be determined simultaneously by spark source mass spectrometry. This project is being conducted by DOE with EPA pass-through funds. Term of the contract is from 1976 and is continuing.

3.4.3.4 Monitoring Methods for Characterizing Water Pollutants

Identification of Components of Energy-Related Wastes and Effluents

Two contractors have worked to identify components of energy-related wastes and effluents. The first contract, performed by Research Triangle Institute, Research Triangle Park, NC, has been completed. Their work was reported in EPA Research Report No. EPA-600/7-78-004, January 1978. The second contract is being performed by Gulf South Research Institute, New Orleans, LA, and will be completed by the end of 1979.

Contract work was divided into two phases. Phase A consisted of a state-of-the-art summary to determine which energy-related solid wastes and aqueous effluents had already been analyzed to identify and measure pollutants. Information concerning past and current relevant projects was summarized by both contractors. These reports indicated projects concerned with analysis of samples from coal mines, oil refineries, oil shale processors, coal-fired power plants, coal liquefaction and coal gasification. The summary prepared by Research Triangle Institute was included in the EPA report mentioned above. The report prepared by Gulf South Research Institute is currently being printed and will be available as an EPA research report about May 1979.

Phase B of both contracts consisted of selecting sampling sites, collecting samples, and analyzing samples. Analysis of samples for all elements except mercury was performed by spark source mass spectrometry. Mercury determinations were carried out using the cold vapor atomic absorption technique. Organic compounds in the samples were identified by gas chromatography-mass spectrometry. Volatile organic compounds were determined using purge-and-trap techniques. Semivolatile organic compounds were extracted with methylene chloride, once at a high sample pH and once at a low sample pH. Organic compounds identified were quantified using molar response ratios. Six oil shale process effluent samples were collected at the Anvil Points site, Rifle, Colorado, and are being analyzed at Gulf South Research Institute.

3.4.3.5 Development of Techniques for Measurement of Organic Water Pollution

Comparison of Carbon and Resin Sorption of Organic Materials

In studies at Iowa State University performed with EPA pass-through to DOE funds, synthetic resins of different chemical composition and activated carbons produced by different processes were used to analyze drinking water. Use of polystyrene-divinylbenzene (PS-DVB) porous polymers led to the recovery of greater amounts of gas chromatographable organic materials from these water supplies than did the use of other adsorbents evaluated. Materials accumulated were tested for the presence of potential carcinogens using the Salmonella mutagenicity assay (Ames Test). Mutagenic activity was detected in materials recovered using PS-DVB resins more frequently than in materials recovered using other adsorbents. These findings indicate that the PS-DVB resins are superior for accumulating gas chromatographable and potentially carcinogenic materials from drinking water.

Adsorbents were also compared for recovering organic materials from shale oil process water and from water obtained from test wells in the vicinity of coal storage piles. No adsorbent tested accumulated more than a fraction of the organic materials present in the shale oil product water. Strong base anion exchange resins and acrylic ester resins, however, were the most effective adsorbents tested. No adsorbent tested accumulated detectable amounts of organic materials from the coal mine storage water.

Most of the goals of the carbon resin comparison studies have been accomplished. It has been found that resins of the PS-DVB type are the most effective agents for accumulating gas chromatographable organic materials from water. Other work has shown that reverse osmosis accumulation procedures are effective for high molecular weight and ionic organic materials. A brief study will determine if these two techniques can be combined to yield a procedure applicable to the isolation of all organic materials from drinking water.

Characterization of Dirty Aqueous Effluents from Energy Generating Sources

This project, initiated late in FY 1978, is also conducted at Iowa State University. The focus of this study is on the development of procedures for the characterization and quantitation of potentially hazardous constituents in dirty aqueous effluents.

Samples of "typical" effluents will be obtained from pilot and demonstration scale facilities now in operation. Attempts will be made to modify existing techniques or to develop new techniques for isolating organic contaminants from these effluents. Work will begin on procedures for separating sample components into fractions containing species with similar chemical properties and functionalities. Procedures for the routine determination of priority contaminants will be refined. Capabilities for performing bioassays will be expanded.

Isolation and separation protocols will be finalized. Routine monitoring procedures will be applied to samples taken from operating facilities. Bioassay procedures will be utilized to guide separation and characterization efforts towards those sample components posing the greatest potential threat to the environment.

Developed procedures will be tested on "real" samples. An attempt will be made to identify or characterize all major components and to identify or characterize all components which might have an adverse environmental effect.

Quality Assurance and Instrumentation in Air and Water Pollution

In cooperation with the EPA and other government agencies, the NBS is developing methodology and standard materials for measuring the environmental effects resulting from increased energy production. The NBS Analytical Chemistry Division is initiating research and development in the areas of reference materials, instrumentation, and methods required for monitoring air and water quality associated with energy production. The research and development leading to Standard Reference Materials (SRM) instrumentation and methods are urgently needed for the monitoring of air and water quality associated with increased energy development of many different types. Due to the current and future energy problems facing the U.S., it has become imperative for the rapid development of the internal energy capabilities of this country. In order to

maintain an acceptable level of environmental pollution, the methods devised for increased utilization of these internal energy sources, (e.g., petroleum, coal, uranium, oil shale, geothermal) must be adequately evaluated and monitored for effects on air and water pollution. In order to effectively carry out its responsibilities in these areas, the EPA has requested the assistance of the NBS Analytical Chemistry Division for research and development of SRM's.

The overall approach to be taken involves three basic steps. First, in areas of well-defined pollution effects, the emphasis will be on the development and certification of SRM's to enable effective quantitation. Examples of such well-defined pollution effects include gases in air pollution (e.g., sulfur dioxide, carbon monoxide) and trace metals in water pollution (e.g., mercury, arsenic, lead). Second, in areas of known effects but imperfect measurement methodology, research and development on analytical methods and instrumentation will be undertaken. Examples of these areas include particulates and trace organics in air and water pollution. Third, in areas of new or increased energy production techniques (i.e., coal gasification and liquefaction, uranium production, etc.), a series of workshops will be held to help define the current state-of-the-art, future requirements for analytical reference materials, and methodology for air and water pollution measurements. Term of the contract is from 1975 to 1979.

3.4.3.6 Development of Ambient Monitoring Guidelines

Western Energy-Related Regional Air Quality Monitoring

EMSL/LV is presently engaged in an extensive program to evaluate the existing and potential regional impact of energy development for air quality in the western energy resource development area (WERDA). This study area encompasses an essentially "pristine" eight-state area (Arizona, Colorado, Utah, New Mexico, Montana, Wyoming, North and South Dakota) with extensive proposed fossil fuel resource development. The program's primary objectives are to establish an energy-related air quality baseline, evaluate air quality trends, assess the impacts of specific energy-related development activities, and predict the impact of proposed energy development.

To accomplish these objectives a number of individual programs have been initiated. First, a monitoring and source network inventory was prepared and is being maintained. Air quality monitoring was evaluated and the existing network is being augmented in terms of sampling locations, frequency of sampling, and analyses being conducted. In particular, the analysis of particulate sulfates and nitrates has been added to many of the stations. In addition, a 28-station network was established in the Four Corners states to monitor total suspended particulates, sulfates, nitrates, and selected trace elements. The accuracy and intercompatibility of the data collected by the various networks in the study area are determined by a quality assurance program encompassing federal, state, and local monitoring programs.

To assess the impact of energy development and visibility, a 14-station visibility monitoring network has been established in the Four Corners states. A visibility monitoring research station has been operating in Canyonlands National Park since the spring of 1978. At this station, various monitoring techniques are compared and evaluated. Beginning in the summer of 1979, a network of 40 fine particulate monitoring stations will be deployed and operated in the WERDA for a period of 15 months. This network will provide information on the composition and concentration of the fine particulates. In addition to these ground-based programs, an instrumented air quality aircraft is being flown to characterize dispersion from the sources and assess long-range regional transport of air pollutants. These field measurements are being used to validate regional scale atmospheric diffusion models for predicting the impact of various energy development scenarios.

Air and Water Monitoring Guidelines for Advanced Coal Conversion and Combustion Plants

Within an overall coal conversion-oil shale effort, Dalton-Dalton-Newport, Inc., Cleveland, Ohio, is developing ambient monitoring guidelines for commercial scale in situ and/or modified in situ oil shale developments. The monitoring guidelines will include priority ranking of potential pollutants, recommended sampling and analysis procedures, a preliminary quality assurance program design, and recommended data management plans. A monitoring guideline document will be prepared for in situ oil shale development. This project is being sponsored through EMSL-LV. Term of the contract is from October 1978 to October 1981.

3.4.4 Environmental Transport Processes

The Mineralogy of Overburden as Related to Groundwater Chemical Changes in Strip Mining of Coal, In Situ Coal Gasification, and Oil Shale Retorting

In this Colorado School of Mines Research Institute study, overburden cores and groundwater samples will be chemically and physically characterized. It is anticipated that this effort will generate scientific information, predictable in nature, which can be extrapolated to other areas of mining activity. The overall objective of this research is to provide regulatory

agencies and the mining community with a method to predict groundwater changes resulting from coal strip mining, in situ coal gasification, and oil shale retorting. This is a four-year effort, in which the third year will concentrate on oil shale, with a report expected in 1979.

Organic Fractionation and Solute Transport Study

The objective of this LETC study is to develop a unique organic solute characterization study based on sorption of both true in situ and simulated in situ retort waters. An effort will be made to relate DOE fractionation analysis of retort waters to sorptive interactions with retorted shale, so that predictions can be made concerning availability, potential movement and ultimate fate of organic solute from retorted shale to adjacent ground waters.

Solute analysis will emphasize quantitative organic analysis of fractions obtained in DOE fractionation. A material balance approach, based on carbon, will be used and hopefully identify 50-75 percent of organic carbon. This information will be used to identify compounds whose transport is of greatest environmental significance.

Environmental Pathways of Selected Chemicals in Freshwater Systems

Environmental exposure assessment models and laboratory procedures for predicting the pathways of potentially harmful chemicals in freshwater environments were described in Part I of this report EPA-600/7-77-113, Environmental Pathways of Selected Chemicals in Freshwater Systems, October 1977. In Part II, EPA-600/7-78-074, May 1978, procedures were developed for measuring the rates of volatilization, photolysis, oxidation, hydrolysis, and biotransformations as well as the sorption partition coefficients on natural sediments and on a mixture of four bacteria. The results were integrated with a simple computer model to predict the pathways of chemicals in ponds, rivers, and lakes. This second part of the project report describes the successful application of these procedures to 11 chemicals of environmental interest. The chemicals were p-cresol, benz(a)anthracene, benzo(a)pyrene, quinoline, benzo(f)quinoline, 911-carbazole, 7H-dibenzo(c,g)carbazole, benzo(b)thiophene, and dibenzothiophene, which might be found in the effluents of plants using or processing fossil fuels, and methyl parathion and mirex, which are agricultural pesticides. This work was performed by SRI International for EPA ERL/Athens, Georgia.

3.5 END USE

3.5.1 Shale Oil Refining

Emission and Process Water Monitoring During Shale Oil Refining

On November 1, 1978, EPA entered into an Interagency Agreement (IAG) with the Energy and Natural Resources Research and Development Office of the Department of the Navy, to measure fugitive emissions during the refinery processing of Navy shale oil and to collect various samples for health and ecological research purposes. The Navy Department in conjunction with the Department of Energy has a multimillion dollar, multiyear program directed towards evaluating oil shale as a source of defense mobility fuels. As part of that program, the Navy procured approximately 100,000 barrels of shale oil produced by the Paraho process. During this past November, at Standard Oil of Ohio's (Sohio) Toledo refinery, the Navy Department had this oil refined into jet and diesel fuels. This represented the first refinery processing of shale oil at this scale. EPA's interest in that activity stems from its desire to obtain as much precommercialization data as possible in order to identify any environmental and health problems that might be associated with the utilization of the shale oil.

To implement the above EPA-Navy Interagency Agreement (IAG), Paraho Development Corporation (PDC), the Navy's prime contractor for obtaining the shale oil, hired Radian Corporation of Austin, Texas to measure and characterize the emissions from these refinery units associated with processing of the shale oil and to collect selected process water samples. The report on this analysis is expected to be published in the summer of 1979.

A foul water condensate sample, the only process water sample collected, has been sent to EPA's R. S. Kerr Environmental Research Laboratory for analysis of priority pollutants. Selected liquid hydrocarbon samples collected were: raw shale oil, hydrotreated shale oil, and precursor gas feed stock. These and an acid sludge sample were in the process of being shipped to the EPA/DOE Chemical Respository at ORNL at the end of February 1979 for distribution to various investigators for health and ecological studies. In vitro and in vivo testing will be performed on these materials along with comparable products derived from petroleum feed stocks and various synfuel products from coal. The effort will be correlated with biological and health studies being performed by the Navy and the American Petroleum Institute.

Plans also call for following the shale oil products through the combustion phase by collecting exhaust effluents for chemical and in vitro toxicology when bench tests begin under the Navy's auspices.

3.5.2 Exhaust Emissions from Shale Derived Fuel Oils

The Combustion Research Branch of IERL/RTP is currently involved in three contractual efforts which include tasks for measuring exhaust emissions from shale derived fuel oils. The first of these efforts is with Pratt and Whitney Aircraft, which is addressing stationary gas turbine engines, while the other two efforts are with Energy and Environmental Research Corporation (EERC) and are addressing package boilers. In each of these contracts the primary focus is the development of low NO_x combustor technology for a variety of fuel oils and is not directed toward an in-depth investigation of shale oil emission characteristics per se.

In order to place the ongoing R&D involving shale oil into better perspective, it is important to note that shale oil has the interesting characteristic that it contains significant amounts of chemically bound nitrogen within the fuel matrix. (The quantity, of course, depends upon the degree and details of distillation.) As such, the potential use of shale oil or similarly coal derived liquids has the potential for increased NO_x emissions relative to the emission levels that would be achieved with a normal distillate fuel oil or with natural gas.

Advanced Combustion Systems for Stationary Gas Turbine Engines

Under the Pratt and Whitney Aircraft contract, a major effort is underway to develop low NO_x combustor design technology for stationary gas turbine engines (SGTE). Previously, within the U.S., SGTE's have burned natural gas, kerosene fuels, and No. 2 distillate oil almost exclusively. Energy resource availability is placing steady economic and political pressure on the gas turbine manufacturers to begin using dirtier fuels or alternate fuels such as shale oil or SRC II. At the very least, they must begin developing the technology to allow these alternate fuels to be burned. Development of NO_x control technology for SGTE's has, of course, been underway for several years now, but, unfortunately, that R&D has been directed at the traditional fuels used by SGTE's. Techniques, such as water injection and super lean combustion, have demonstrated significant NO_x control capabilities for the clean fuels but have been shown to contain significant quantities of bound nitrogen.

In 1975, the EPA recognized this potential problem and embarked on the subject contract to develop NO_x control technology which would be effective for both clean fuels and fuels containing significant amounts of bound nitrogen. To accomplish this goal, the program was structured to investigate a wide spectrum of SGTE combustor concepts in subscale hardware and, based on those subscale results, to select a single combustor concept for testing in full-scale hardware. As regards fuels used in these tests, prime consideration was given to the fact that the combustor concepts could best be screened and evaluated on distillate cut fuels without incurring the added complexity associated with the ash, tars, and high viscosity of residual oils. To that end, test work has proceeded on three primary fuels: No. 2 distillate, No. 2 distillate doped to 0.5 percent nitrogen by pyridine addition, and a distillate cut shale oil. The shale oil used in these tests was obtained from the Navy and was a diesel fuel marine (DFM) cut from the Paraho project. Analysis of this product revealed a 0.25 percent nitrogen content, which is typical of the nitrogen content of many No. 6 residual oils. Thus, from a NO_x control standpoint, this particular shale oil cut was an ideal choice for the intended purposes.

Due to the limited quantities of DFM available (50 barrels), the majority of the development work was performed with the straight No. 2, and the doped distillate with the DFM was used as a check fuel and for verification testing. Results from the contract to date have been identification of a combustor concept which produces NO_x in the 25 to 40 ppm range (at 15 percent O_2) on clean fuels and less than 75 ppm on doped distillate and shale oil. The above cited results were obtained in the subscale testing and are currently being verified in full-scale hardware.

From the standpoint of emissions, it is interesting to note that the shale oil with 0.25 percent nitrogen produced NO_x which was comparable to the No. 2 distillate doped with 0.5 percent nitrogen. This result is most certainly due to the fact that pyridine has a lower boiling point than the temperature at which nitrogen is evolved from the DFM. A full report on this contractual effort is due around the end of September 1979.

Development and Optimization of Low NO_x Burner Designs for Heavy Liquid Fuel-Fired Package Boilers

R&D activities directed toward the development of low NO_x burners for oil-fired package boilers has been underway for several years. In this program, primary interest is with the burning of residual fuel oils in both firetube and watertube package boilers. This program is a continuing effort, being performed by Energy Environmental Research Corporation.

Early in the program, it was discovered that a significant degree of NO_x control could be achieved with residual fuel oil firing through the application of staged combustion techniques and/or through the control of the fuel/air mixing patterns established by the burner. The maximum degree of NO_x control was limited by the onset of unacceptable smoke emissions. Further, both the baseline NO_x emissions and an attainable degree of control were found to vary depending upon the source of the residual oil. To follow up on this fuel dependency, a wide range of residual fuel oils were collected, analyzed for chemical composition and distillation characteristics, and fired in a small research furnace (approximately 100,000 Btu/hr). To date approximately 28 residual oil, fuel blends, and alternate nitrogen-containing liquid fuels, including shale distillate and crude shale, have been tested. Baseline tests show that under conditions of a high degree of early mixing between the fuel and oxidizer and fuel lean conditions in the early part of the flame, both total NO_x and the NO_x attributable to oxidation of the fuel-bound nitrogen correlate well with the nitrogen content in the fuel. Further, it has been shown that for these fuels approximately 75 to 80 percent of the exhaust NO_x is related to the fuel-bound nitrogen. The degree of control attainable appears to be a function of the conditions established within the boiler and on several characteristics of the fuel. In addition to the amount of nitrogen in the fuel matrix, another controlling fuel characteristic is how tightly the nitrogen is bound within the fuel. For fuels such as the distillate shale oil or SRC II with the nitrogen predominantly bound in light fractions, control of NO_x emissions is relatively easy, when compared to fuels such as the residual oil from Alaska's North Slope which has the nitrogen bound in very heavy ends. No firm conclusions have yet been reached from this research but valuable clues are being derived. Recently a large quantity of the residual oil left from refining a Paraho crude shale oil was secured from the Navy and will be used in tests on package boilers in the 2 to 10 × 10^6 Btu/hr size range. Results from the EERC efforts should first be reported by the end of September 1979, while the latter results and associated reports are scheduled for early 1981.

Emissions From Vehicles Using Oil Shale Derived Fuels

Emission Control Technology Division, Ann Arbor, is primarily interested in the impact of oil shale derived fuels on the emissions from mobile sources (light and heavy duty vehicles, motorcycles, aircraft, locomotives, etc.). The principal area of interest is whether or not the use of oil shale derived fuels in mobile sources will cause an increase, relative to conventional fuels, in an emission parameter, that could thus represent a potential hazard to public health, welfare, or safety.

In one effort that is planned, a vehicle operating on an oil shale derived gasoline would be tested for a variety of exhaust emissions including HC, CO, NO_x, particulates, sulfates, sulfides, organic amines, etc. The emission data will be compared to data gathered under the same conditions using conventional petroleum-based gasoline.

In another effort, an oil shale derived fuel would be used to operate a light duty diesel vehicle, and analyses would be made for a variety of resultant emissions. These emissions would include the regulated emissions of HC, CO, and NO_x as well as several of the currently unregulated emissions of particulates (including mass emission rate of particulates, associated organics, benzo(a)pyrene, and elemental analysis of the organics), aldehydes, phenols, smoke, and odor. ECTD also plans bioassay studies using the Ames test on both the fuel and its emission products. EPA has already done work of this nature on a variety of commercially available fuels and, therefore, has an extensive data base with which to compare the emissions from the oil shale derived fuel.

Table 1

CURRENT PROGRAM STATUS SUMMARY

Title	Sponsor	Performing Organization	Duration	Contact
OVERALL ASSESSMENTS				
Pollution Control Guidance for Oil Shale Development	IERL-Ci	EPA Oil Shale Work Group	1 yr.	E. R. Bates 513/684-4417 T. Thoem 303/837-5914
EPA-Industry Forum to Research Technical and Regulatory Problems for Shale Development	OEMI/Hq IERL-Ci	C.K. Geo-Energy	8 mo.	W.N. McCarthy,Jr. 202/755-2737 A. Christianson 513/684-4207
Integrated Assessment: Socioeconomic Consequences of Coal and Oil Shale Development	EPA pass-through to USDA	USDA	39 mo.	J. Barse 202/447-4859
Technology Assessment of Western Energy Resource Development	OEMI	University of Oklahoma	3 yr.	M. Devine 405/325-2554
EXTRACTION AND HANDLING				
Technologies for Controlling Adverse Effects of Mining on Forest, Range and Related Freshwater Ecosystems	EPA pass-through to USDA	USDA	4 yr.	R. D. Hill 513/684-4410
Water Quality Hydrology Affected by Oil Shale Development	IERL-Ci	Colorado State University	5 yr.	E. F. Harris 513/684-4417
Vegetative Stabilization of Paraho Spent Oil Shale	IERL-Ci	Colorado State University	3 yr.	E. F. Harris 513/684-4417
Vegetative Stabilization of Spent Oil Shale	IERL-Ci	Colorado State University	4 yr.	E. R. Bates 513/684-4417
Fugitive Dust from Oil Shale Extraction	IERL-Ci	TRW	2 yr.	E. R. Bates 513/684-4417
Trace Element Analysis on Cores From the Naval Oil Shale Reserves	IERL-Ci USN, DOE	Lawrence Berkeley Laboratory	1 yr.	E. R. Bates 513/684-4417
Leaching Characteristics of Raw Surface Stored Oil Shale	IERL-Ci	Colorado State University	2 yr.	E. R. Bates 513/684-4417
Air Emissions from Old Shale Waste Sites	IERL-Ci DOE	Science Applications, Inc.	1 yr.	E. R. Bates 513/684-4417
PROCESSING				
Assessment of Environmental Impacts from Oil Shale Development	IERL-Ci	TRW/DRI	2 yr.	T. Powers 513/684-4363
Oil Shale Symposium: Sampling Analysis and Quality Assurance	IERL-Ci	DRI	1 yr.	P. Mills 513/684-4303
Sampling and Analysis of the Paraho Surface Retort	IERL-Ci	TRW/DRI	3 yr.	T. Powers 513/684-4363

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Table 1

CURRENT PROGRAM STATUS SUMMARY (Continued)

Title	Sponsor	Performing Organization	Duration	Contact
PROCESSING (Cont.)				
Sampling and Analysis for Retort and and Combustion Gases at the Paraho Shale Oil Demonstration Plant	IERL-Ci	TRW	1 yr.	T. Powers 513/684-4363
Environmental Characterization of In Situ Oil Shale Processing	IERL-Ci	Monsanto Research Corp.	1 yr.	T. Powers 513/684-4363
Assessment of Oil Shale Retort Wastewater Treatment and Control Technology	IERL-Ci	Monsanto Research Corp.	3 yr.	T. Powers 513/684-4363
Air Pollution Investigations of Oil Shale Retorting: In Situ and Surface	IERL-Ci	Monsanto Research Corp.	3 yr.	R. Thurnau 513/684-4439
Analytical Methods Manual for Oil Shale Effluents	IERL-Ci	DRI	3 yr.	R. Thurnau 513/684-4439
Overview of the Environmental Problems of Oil Shale Development	IERL-Ci	DRI	28 mo.	R. Thurnau 513/684-4439
Distribution of As, Cd, Hg, Pb, Sb and Se During In Situ Oil Shale Retorting	EPA pass-through to DOE	Lawrence Berkeley Laboratory	1 yr.	P. Mills 513/684-4303
Portable Zeeman Atomic Absorption Mercury Monitor	EPA pass-through to DOE	Lawrence Berkeley Laboratory	1 yr.	P. Mills 513/684-4303
ENERGY-RELATED PROCESSES AND EFFECTS				
Health Effects				
Repository for Alternate Energy Source Material for Toxicity Testing	EPA pass-through to DOE	Oak Ridge National Laboratory	3 yr.	D. Coffin 919/541-2586
Air, Water, and Multiroute and Health Effects from Pollutants Associated with Energy Development	HERL-Ci	HERL-Ci	12 mo.	J. F. Stara 513/684-7401
Chemical Rate, Detection, Metabolism and Bioaccumulation Potential of Shale Oil Components and the Effects of Marine Diesel Fuel on Marine Organisms	ERL-Gulf Breeze	ERL-Gulf Breeze	12 mo.	N. Richards 904/932-5311
Effect of Alternate Energy Source Material on Whole Animal Carcinogenesis by Percutaneous Application of Extracts and Fractions to Mice	EPA pass-through DOE	Oak Ridge National Laboratory	2 yr.	D. Coffin 919/549-2586
Morphological Variants in Damaged Sperm	EPA pass-through to DOE	Lawrence Livermore Laboratory	5 yr.	G. Stapleton 301/353-5039
Detection of Early Changes in Lung Cell Cyntology by Flow Systems Analysis Techniques	EPA pass-through to DOE	Los Alamos Scientific Laboratory	1976-in prog.	G. Duda 301/353-3651

Table 1

CURRENT PROGRAM STATUS SUMMARY (Continued)

Title	Sponsor	Performing Organization	Duration	Contact
ENERGY-RELATED PROCESSES AND EFFECTS (Cont.)				
Health Effects (Cont.)				
Mortality, Morbidity, and Industrial Hygiene Study of Oil Shale Workers	NIOSH	NIOSH	2 yr.	J. Costello 304/599-7474
Determination of the Influence of Mineral Cofactors in Conjunction with Carcinogens from Energy-Related Materials	HERL-RTP	Northrop Services	32 mo.	D. Coffin 919/549-2586
In Vivo Screening for Gene Mutation in Mouse Germ and Somatic Cells	EPA pass-through to DOE	Oak Ridge National Laboratory	1976-in prog.	G. Stapleton 301/353-5039
The Carcinogenic Effects of Petroleum Hydrocarbons on Selected Marine Estuarine Organisms	EPA pass-through to NIEHS	University of Washington	2 yr.	P. E. Schambra 919/541-3457
Determination of the Effects of Material from Alternate Energy Sources on Upper Respiratory Tract Clearance Mechanisms	HERL-RTP	Ball State University	42 mo.	D. Gardner 919/549-8411
Quantitative Mutagenesis Testing in Mammalian Cellular Systems	EPA pass-through to DOE	Lawrence Livermore Laboratory	5 yr.	G. Stapleton 301/353-5039
Development of Cytochemical Markers for Cell Transformation and Carcinogenesis	EPA pass-through to DOE	Lawrence Livermore Laboratory	5 yr.	G. Duda 301/353-3651
Somatic Cell Genetics	EPA pass-through to DOE	Los Alamos Scientific Laboratory	2 yr.	G. Duda 301/353-3651
Analysis of the Effects of Energy-Related Toxic Materials to Karotype Stability in Mammalian Cells	EPA pass-through to DOE	Los Alamos Scientific Laboratory	1976-in prog.	G. Duda 301/353-3651
Effects of Products of Coal and Oil Shale Conversion on Cell Cycle Kinetics and Chromatin Structure	EPA pass-through to DOE	Los Alamos Scientific Laboratory	1976-in prog.	G. Stapleton 301/353-5039
Mutagenicity Assay of Fractionated Coal Conversion and Shale Oil In Situ Retorting Products	EPA pass-through to DOE	Oak Ridge National Laboratory	1975-in prog.	G. Stapleton 301/353-5039
The Quantitative Evaluation of Hazardous Chemicals Using a Closed Aquatic Test System	EPA pass-through to DOE	Brookhaven National Laboratories	1976-in prog.	G. Duda 301/353-3651
The Interaction of Chemical Agents Present in Oil Shale with Biological Systems	EPA pass-through to NIEHS	NIEHS-RTP	1977-in prog.	L. G. Hart 919/541-3205
Development of Permanent Epithelial Cell Lines	EPA pass-through to DOE	Oak Ridge National Laboratory	1976-in prog.	G. Stapleton 301/353-5039

Table 1

CURRENT PROGRAM STATUS SUMMARY (Continued)

Title	Sponsor	Performing Organization	Duration	Contact
ENERGY-RELATED PROCESSES AND EFFECTS (Cont.)				
Health Effects (Cont.)				
Development of an In Vitro Assay for Cocarcinogenesis of Coal/Oil Shale Derivatives	EPA pass-through to DOE	UCLA School of Medicine	1976-in prog.	G. Stapleton 301/353-5039
Ecological Effects				
Effects of Aqueous Effluents from In Situ Fuel Processing Technologies on Aquatic Systems	ERL-Duluth LETC	University of Wyoming	5 yr.	L. Mueller 218/727-6692 X529
Chemical and Biological Characterization of Oil Shale Processing and Coal Conversion	ERL-Duluth	Colorado State University	5 yr.	L. Mueller 218/727-6692 X529
Measurement and Monitoring				
Oil Shale Area Meteorological Data Analysis	Region VIII	CDM Limnetics	16 mo.	T. Thoem 303/837-5914
Air Quality and Surface Wind Monitoring in Colorado	Region VIII	Colorado Dept. of Health	5 yr.	T. Thoem 303/837-5914
Upper Air Meteorological Data Collection	OEMI/ Region VIII	Aeromet, Inc.	5 yr.	T. Thoem 303/837-5914
Visibility Monitoring in Piceance Basin	Region VIII	Occidental Petroleum	Starts 1979	T. Thoem 303/837-5914
Monitoring the Impact of Oil Shale Extraction on Groundwater Quality	EMSL-LV	General Electric	5 yr.	L. McMillion 702/736-2969
Energy-Related Water Monitoring Data Integration	EMSL-LV	EMSL-LV	5 yr.	R. Thomas 702/736-2969
Water Quality and Geochemistry of Shallow Aquifers of Piceance Creek, Colorado	EPA pass-through to USGS	USGS	1974-in prog.	F. A. Kilpatrick 703/860-6846
Water Quality Monitoring on White River, Parachute Creek and Logan Wash in Oil Shale Areas of Western Colorado	EPA pass-through to USGS	USGS	6 yr. in prog.	F. A. Kilpatrick 703/860-6846
Collection of Geochemical Data in the Piceance Creek Structural Basin of Colorado	EPA pass-through to USGS	USGS	2 yr.	F. A. Kilpatrick 703/860-6846
Definition of Potentiometric Surface of Shallow Aquifers in Piceance Creek Impacted by Oil Shale	EPA pass-through to USGS	USGS	3 yr.	J. Weeks 303/234-5092
Water Quality Monitoring Techniques Evaluation	EMSL-LV	EMSL-LV	4 yr.	W. L. Kinney 703/736-2969
Assessment of Macroinvertebrate Monitoring Techniques	EMSL-LV	EMSL-LV	1 yr.	W. L. Kinney 703/736-2969

Table 1

CURRENT PROGRAM STATUS SUMMARY (Continued)

Title	Sponsor	Performing Organization	Duration	Contact
ENERGY-RELATED PROCESSES AND EFFECTS (Cont.)				
Measurement and Monitoring (Cont.)				
Instrumentation and Methods for Characterizing Aqueous Effluents from Oil Shale	EPA pass-through to DOE	Oak Ridge National Laboratory	1976-in prog.	B. Clark 202/755-2673
Identification of Components of Energy-Related Wastes and Effluents	ERL-Athens	Gulf South Research Institute	3 yr.	A. Alford 404/546-3525
Comparision of Carbon and Resin Sorption of Organic Materials	EPA pass-through to DOE	Iowa State University	3 yr.	G. Goldstein 301/353-5348
Characterization of Dirty Aqueous Effluents from Energy Generating Sources	EPA pass-through to DOE	Iowa State University	3 yr.	G. Goldstein 301/353-5348
Quality Assurance and Instrumentation in Air and Water Pollution	EPA pass-through to NBS	NBS	4 yr.	J. McNesby 301/921-2446
Western Energy-Related Regional Air Quality Monitoring	EMSL-LV	EMSL-LV	5 yr.	D. McNelis 702/736-2969
Air and Water Monitoring Guidelines for Advanced Coal Conversion and Combustion Plants	EMSL-LV	Dalton-Dalton-Newport	3 yr.	R. Bateman 702/736-2969
Environmental Transport Studies				
The Mineralogy of Overburden as Related to Groundwater Chemical Changes in Strip Mining of Coal, In Situ Coal Gasification, and Oil Shale Retorting	ERL-R.S. Kerr	CSMRI	4 yr.	R. Newport 405/332-8800
Organic Fractionation and Solute Transport Study	ERL-R.S. Kerr	LETC	1 yr.	R. Newport 405/332-8800
Environmental Pathways of Selected Chemicals in Freshwater Systems	ERL-Athens	SRI International	1977-in prog.	R. R. Lassiter 404/250-3162
END USE				
Emission and Process Water Monitoring During Shale Oil Refining	EPA pass-through to Dept. of Navy	Radian Corporation	6 mo.	W.N. McCarthy, Jr. 202/755-2737
Advanced Combustion Systems for Stationary Gas Turbine Engines	IERL-RTP	Pratt & Whitney Aircraft	41 mo.	W. S. Lanier 919/541-2432
Development of Optimization of Low-NO_x Burner Designs for Heavy Liquid Fuel Fired Package Boilers	IERL-RTP	Energy and Environmental Research Corp.	2 yr.	W. S. Lanier 919/541-2432
Emissions from Vehicles Using Oil Shale Derived Fuels	ECTD	ECTD	1 yr.	R. J. Garbe 313/668-4262

APPENDICES

Appendix A

EPA PUBLISHED AND TO-BE-PUBLISHED REPORTS ON OIL SHALE

EPA No.	NTIS No.*	Title and Date
OVERALL ASSESSMENTS		
EPA-600/7-79-089		"EPA Program Status Report: Oil Shale 1979 Update," (March 1979)
EPA-600/7-79-083		"Energy from the West; Policy Analysis Report," University of Oklahoma (March 1979)
EPA-600/7-79-082a,b		"Energy from the West; Impact Analysis Report," 2 Vol. University of Oklahoma (March 1979)
EPA-600/7-79-060a-e		Energy from the West; Energy Resources Development Systems Report," 5 Vol. University of Oklahoma (March 1979)
EPA-600/7-79-039		"Compendium Reports on Oil Shale Technology," General Electric Company-TEMPO (January 1979)†
EPA-600/7-78-020		"EPA Program Status Report: Oil Shale," (February 1978)
EPA-600/9-77-033	NA**	"Oil Shale and the Environment," EPA Decision Series (October 1977)
EPA-600/7-77-072a-d	NA	"Energy from the West: A Progress Report of a Technology Assessment of Western Energy Resource Development," 4 Vol. University of Oklahoma, Radian Corporation (July 1977)
EPA-600/7-77-037	PB-268-062/7BE	"Water Requirements for Steam Electric Power Generation and Synthetic Fuel Plants in Western U.S.," University of Oklahoma (April 1977)
EPA-600/7-77-032	NA	"Interagency Energy/Environment R&D Program-Status Report III," OEMI (April 1977)
EPA-600/7-77-024	PB-266-256/7BE	"Western Energy/Environment Monitoring Study: Planning and Coordination Summary," EPA/OEMI (March 1977)
EPA-600/7-77-015	PB-266-292/2BE	"Monitoring Environmental Impacts of the Coal and Oil Shale Industries: Research and Development Needs," Radian Corporation (February 1977)
EPA-600/5-76-001	PB-252-034/AS	"First Year Work Plan for a Technological Assessment of Western Energy Resource Development," University of Oklahoma (March 1976)
EPA-600/2-75-070	PB-247-140/AS	"EPA Program Status Report: Synthetic Fuels Program," Stanford Research Institute (October 1975)

† This state-of-the-art survey supports a study designing a groundwater quality monitoring program for oil shale operations such as that proposed for Federal Oil Shale Lease Tracts U-a and U-b.

EPA PUBLISHED AND TO-BE-PUBLISHED REPORTS ON OIL SHALE (Continued)

EPA No.	NTIS No.*	Title and Date
EXTRACTION AND HANDLING		
EPA-600/7-78-021***		"Vegetative Stabilization of Spent Oil Shales: Vegetation Moisture, Salinity and Runoff, 1973-1976 (March 1978)
EPA-600/2-76-064	PB-252-649/AS	"Atmospheric Pollution Potential from Fossil Fuel Resource Extraction, Onsite Processing and Transportation," Radian Corporation (March 1976)
PROCESSING		
EPA-600/7-79-075		"Technological Overview Reports for Eight Shale Oil Recovery Processes," TRW/DRI (March 1979)
EPA-600/7-78-065		"Sampling and Analysis Research Program at the Paraho Shale Oil Demonstration Plant," TRW/DRI (April 1978)
EPA-625/9-77-002	NA	"Environmental Sampling of the Paraho Oil Shale Retort Process at Anvil Points," Executive Briefing, EPA Technology Transfer Series (October 1977)
EPA-600/7-77-069	NA	"A Preliminary Assessment of Environmental Impacts from Oil Shale Development," TRW/DRI (July 1977)
EPA-908/4-78-003		"Trace Elements Associated with Oil Shale and the Processing," (May 1977)
ENERGY-RELATED PROCESSES AND EFFECTS		
EPA-600/7-79-023		"Groundwater Quality Monitoring of Western Oil Shale Development: Identification and Priority Ranking of Potential Pollution Sources," General Electric Company-TEMPO (January 1979)
EPA-600/3-78-097	PB-291251/AS	"Environmental Effects of Oil Shale Mining and Processing, Part II: The Aquatic Macroinvertebrates of the Piceance Basin, Colorado, prior to Oil Shale Processing (October 1978)
EPA-600/3-78-096	PB-289874/AS	"Environmental Effects of Oil Shale Mining and Processing, Part I: Fishes of Piceance Creek Colorado, Prior to Oil Shale Processing" (October 1978)
EPA-908/2-78-001		"Water and Air Quality Trends in Region VIII," (March 1978)
EPA-908/4-77-011		"Ambient Air Quality Monitoring Network EPA Region VIII Energy Areas (October 1977)
EPA-660/2-74-067	PB-236-608/AS	"Pollutional Problems and Research Needs for an Oil Shale Industry," EPA, Robert S. Kerr Environmental Research Laboratory (June 1974)
EPA-650/2-74-099	PB-241-942/AS	"Environmental Considerations for Oil Shale Development," Battelle Columbus Labs (October 1974)

EPA PUBLISHED AND TO-BE-PUBLISHED REPORTS ON OIL SHALE (Continued)

EPA No.	NTIS No.*	Title and Date
ENERGY-RELATED PROCESSES AND EFFECTS (Cont.)		
EPA-R-3-73-011a	PB-221-343	"Effects of Chemical Variations in Aquatic Environments - Vol. 1: Biota and Chemistry of Piceance Creek," Colorado State University (February 1973)
EPA-TR-76-74	PB-259-070-T/BE	"Some Data on the Composition of Neutral Oxygen Compounds of Estonian Shale Resins which Boil Under 200°C," USSR (1972)
EPA-TR-76-54	PB-258-920-T/BE	"The Carcinogenic Properties of Oil Shale Products and the Possibilities of Prophylaxis Cancer," Institute of Experimental and Clinical Medicine, Tartusk State University, USSR (1972)
EPA-TR-76-80	PB-258-790-T/BE	"Aromatic Hydrocarbons in Generator Shale Resin," USSR (1971)
END USE		
EPA-600/2-76-177b	PB-260-475/9BE	"Fuel Contaminants: Vol. 2., Removal Technology Evaluations," Battelle Columbus Labs (September 1976)
EPA-600/7-76-004b	PB-255-995/AS	"Impact of Synthetic Liquid Fuels Development Automotive Market: Vol. 2.," Stanford Research Institute (July 1976)
EPA-600/7-76-004a	PB-255-994/AS	"Impact of Synthetic Liquid Fuel Development Automotive Market: Vol. 1, Summary," Stanford Research Institute (June 1976)

* Available through the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151, (703) 557-4650. Availability of reports from EPA may be obtained by contacting OEMI-Hq. (W.N. McCarthy, Jr.) (202) 755-2737.

** Not Available

*** Available from the Resource Extraction and Handling Division, Industrial Environmental Research Laboratory, U.S. EPA, Cincinnati, Ohio 45268, (513) 684-4417.

Appendix B

GENERAL REFERENCES ON OIL SHALE

Ashland Oil, Inc., and Shell Oil Company, "Oil Shale Tract C-b Detailed Development Plan and Related Materials," 2 volumes, February 1976.

Booz, Allen and Hamilton, Inc., "Engineering, Systems Engineering, and Management Support Service for Preparation of the Naval Oil Shale Reserve Master Development Plan," August 1977.

Cameron Engineers, Inc., "A Technical and Economic Study of Candidate Underground Mining Systems for Deep, Thick Oil Shale Deposits," prepared for the U.S. Bureau of Mines, October 1976.

Cameron Engineers, Inc., "Oil Shale Seminar: Conducted for the Department of the Navy, Office of Petroleum and Oil Shale Reserves," September 1977.

Cameron Engineers, Inc., "Synthetic Fuels Data Handbook," compiled by Thomas Hendrickson, 1978.

Cameron Engineers, Inc., "Synthetic Fuels Quarterly Report," various issues.

Colorado School of Mines, "Proceedings of the Ninth Oil Shale Symposium," Volume 71, No. 4, October 1976. (Proceedings of Symposiums 1 through 8 are also available).

Radian Corporation, "A Western Regional Energy Development Study," 4 Volumes, August 1975.

Radian Corporation, "Guidelines for Monitoring Research-Scale In Situ Energy Process," Final Report, September 1976.

Rio Blanco Oil Shale Project, "Revised Detailed Development Plan, Tract C-a," May 1977.

Schmidt-Collerus, Dr. Josef J., "The Disposal and Environmental Effects of Carbonaceous Solid Wastes from Commercial Oil Shale Operations," First Annual Report, National Science Foundation, January 1974.

Smithsonian Science Information Exchange, Inc., "Oil Shale," Custom search on ongoing oil shale projects, October 1977.

Thorne Ecological Institute, "The Colony Environmental Study - Parachute Creek, Garfield County, Colorado," prepared for Colony Development, Atlantic Richfield, Operator, 1974.

U.S. Department of Interior, "Final Environmental Statement for the Prototype Oil Shale Leasing Program," 6 volumes, 1973.

U.S. Department of Interior, Geological Survey, "Organic-Rich Shale of the United States and World Land Areas," USGS Circular 523, 1965.

U.S. Department of Interior, Geological Survey, "Simulated Effects of Oil Shale Development on the Hydrology of Piceance Basin, Colorado," Professional Paper 908, 1974.

U.S. Federal Energy Administration, "Project Independence Report," 1974.

White River Shale Project, "Detailed Development Plan - Federal Lease Tracts U-a and U-b," 2 volumes, 1976.

Appendix C

WORLD RESOURCES AND DEVELOPMENT HISTORY

Oil shale, by one name or another, occurs on all continents and is known to exist in nearly three dozen countries. Few of the known occurrences and practically none of the large occurrences have ever been completely explored. The principal exception is in the Green River Formation in Colorado, Utah, and Wyoming. Total world resources are thus unknown, but it must be measured in hundreds of trillions of barrels. Asia is believed to contain the most oil shale, with Africa running a close second. Still, the Green River deposit is the largest single known concentration of hydrocarbons in the world, covering approximately 11 million acres and containing an estimated four trillion barrels of oil equivalent above an assay of five GPT.

USA

The Ute Indians and their predecessors probably used oil shale as a fuel long before the white man found his way to the Piceance Creek basin. Later on, the Mormons distilled oil from shale near Juab, Utah where the ruins of an old retort still exist.

It wasn't until World War I that serious interest was given to utilizing Green River oil shale. More than 50 oil shale companies had operated in the eastern U.S. prior to Colonel Drake's Pennsylvania oil well, drilled in 1859. These early operations were crude, and no attempt had ever been made to apply the technology to the deposits of western shale discovered in the 1880's.

Western oil shale activity began in the 1890's in Nevada. A businessman named Robert Catlin acquired oil shale properties near Elko between 1890 and 1915. He visited Broxburn, Scotland, in 1901 to study the Scottish operations and eventually began R&D with Elko deposits in 1914. A 100-foot shaft was sunk on his property in 1915 and the following year he erected a 20 ton-per-day retort which proved to be unsatisfactory and was later dismantled. In 1917, he incorporated Catlin Shale Products Company.

In 1918, the company began constructing eight 100 ton-per-day retorts which differed in design from the 1915 models. The retorts were in operation in May 1919, and by July the new plant had produced 15,000 gallons of shale oil. The refrigerator plant, wax press, stills, and agitator were added to the plant late in 1919 and in early 1920. Sometime later, the Catlin Company's retorts were shut down. A third retort, 40 feet high and 12-1/2 feet in diameter, was constructed and put in operation in December 1921. This retort was operated intermittently until October 18, 1924. In 1924 the shale oil products were offered for sale for the purpose of testing the market. The products apparently could not be marketed in competition with petroleum products. On December 23, 1930, the company was dissolved. Its operation admittedly was experimental.

The Oil Shale Mining Company was apparently the first group to undertake R&D efforts with Green River Formation oil shale. It was incorporated in Colordo on October 2, 1916, as a public stock company with a capitilization of $100,000. It acquired six mining claims about 15 miles west of DeBeque, Colorado. An externally heated, six to eight ton-per-day batch-type Henderson retort, 18 feet high and 12 to 15 inches in diameter, and a tramway were constructed. By the end of 1918 or the early part of 1919, the company had six of these retorts, only one of which was assembled and operated on an experimental basis. By 1920, the company experimented with a continuous type of retort, invented by its superintendent, A.V. Young, which was subsequently abandoned.

The company produced a few barrels of oil in 1920 and 30 barrels in 1921. Ore for the retorts was obtained from small pits on the claims from 1917 to 1921. By 1926, the company lost its properties through attachments.

The stories of the Catlin Shale works and the Oil Shale Mining Company are illustrative of dozens of similar operations that existed during the decade following World War I. Most operations were experimental in nature and none ever produced more than a few thousand barrels.

By 1925, more than two dozen experimental plants were operating throughout the country, using Devonian as well as Green River shales. But interest in oil shale was not limited to the entrepreneur. Cities Service, Standard Oil of California, and Texaco began acquiring oil shale properties and investigating shale oil production in 1918. Union Oil Company of California followed suit in 1920. Standard of California conducted laboratory retorting experiments in 1920 and from 1925 to 1928.

The U.S. Bureau of Mines built and operated the N-T-U retort from 1925 to 1929, using Colorado oil shale.

During the mid-1920's, Union conducted studies of existing oil shale processes, made analyses of oil shale samples and undertook an oil shale research program. Starting in 1944, it built and operated an experimental retort with a

capacity of two tons per day. In 1948, it completed a 50 ton-per-day retort which was dismantled in 1954. Construction of a 1,000 ton-per-day demonstration plant was started in 1955 on Parachute Creek north of Grand Valley, Colorado. The plant was completed in 1957 and operated until mid-1958.

Mobil Oil Corporation began a research program to evaluate the potential of oil shale in 1943. A pilot plant was built at Paulsboro, New Jersey, and an experimental program was conducted between 1943 and 1945. In 1965 through 1967, Mobil was operator of a six-company group that leased the Anvil Points demonstration facility near Rifle, Colorado, and further developed gas combustion retorting technology.

Texaco's R&D activities also dated to the 1940's. From 1945 to 1947, Texaco prepared a shale oil refining study for the Navy at its own expense. Beginning in 1957, after experimentation with other methods of extracting oil from shale, Texaco built and operated a pilot plant to develop its own hydroretorting process.

Congress passed the Synthetic Liquid Fuels Act in 1944 because of the tremendous demands for liquid fuels imposed by World War II. This led to construction and operation of the Anvil Points Oil Shale Demonstration Facility of the U.S. Bureau of Mines. Six, 25, and 150 ton-per-day pilot plants were operated between 1950 and 1955.

The Paraho Oil Shale Project, which began in 1973, was a three-year program aimed at demonstrating the feasibility of the Paraho process. The program was administered by Development Engineering, Inc., under the leadership of Harry Pforzheimer of SOHIO. The program was conducted at the Anvil Points Oil Shale Facilities near Rifle, Colorado, under lease from DOE. The project was funded by seventeen participating companies. In 1978, the Paraho facility at Anvil Points completed production of 100,000 barrels of shale oil under contract to the U.S. Navy. The Navy intends to have this shale oil refined into military specification products by an independent contractor.

In the 1960's, work was conducted by Colony Development Corporation on the TOSCO Demonstration Plant, and in situ experimental work was conducted by Equity Oil, ARCO, Shell Oil, and the Laramie Energy Technology Center.

In 1968, the Department of the Interior (DOI) instituted the Oil Shale Test Leasing Program. An oil shale leasing study was initiated by COI in October 1969, which subsequently led to the Final Environmental Impact Statement released in August 1973.

Commencing with competitive bid sales in January 1974, the DOI offered the lease of the six selected tracts in Colorado, Utah, and Wyoming, and during the following six months leased four of these tracts, two each in Colorado (Tracts C-a and C-b) and Utah (Tracts U-a and U-b). Neither of the two Wyoming tracts received acceptable bids.

The Rio Blanco Oil Shale project (Tract C-a) is a joint venture of Gulf Oil Corporation and Standard Oil Company (Indiana). In January 1974, Rio Blanco acquired a lease on Tract C-a as part of the Federal Prototype Oil Shale Leasing Program. Rio Blanco initially planned to develop Tract C-a using open pit mining and surface retorting. In March 1976, a Detailed Development Plan outlining this approach was submitted for governmental approval. It soon became apparent that a number of nontechnical factors prevented using this approach. In May 1977, a revised plan based on modified in situ technology was submitted for government approval.

The revised 40-year plan for development of Tract C-a includes a 10-year Modular Development Phase and a 30-year Commercial Phase. The Modular Development Phase will consist of underground retorting only and will be conducted near the center of the commercial mine area during the first 10 years of operation (1977-1986, including construction). During this time period, a number of retorts will be built and burned in sequence to gain operating experience, improve process efficiency, and confirm capital and operating costs for a commercial operation. Commercial scale operating conditions will be demonstrated during this phase with five retorts being developed and burned by 1981.

In order to conduct the modular development program on Tract C-a, Rio Blanco's partners, Gulf and Standard of Indiana have authorized the expenditure of $93 million for the first four years of the program.

Engineering and construction for the Commercial Phase will begin in 1982 after results of the first prototype commercial-size retorts have been analyzed. Completion of commercial-size retorts and support facilities is anticipated to take up to five years. Rio Blanco intends to demonstrate commercial feasibility and other objectives of the prototype oil shale program at an initial rate of about 50,000 BPSD. This production level is anticipated to result in a peak employment of about 1,550 people. Total population for the duration of the project will increase by about 5,800 people as a result of the development.

The C-b Shale Oil Project lease was awarded in April 1974 to a group composed of Ashland Oil, Inc., The Atlantic Richfield

Company, Shell Oil,Inc., and The Oil Shale Corporation (TOSCO). Later, three of the companies withdrew from the project, leaving Ashland Oil. On November 3, 1976, Occidental Petroleum Corporation (Oxy) entered into an agreement with Ashland whereby Oxy gained a 50 percent interest in Tract C-b in exchange for their technology concerning the modified in situ process. In early 1978, an agreement was executed by the two companies giving Oxy 75 percent, and Ashland 25 percent. In late 1978, Ashland announced its withdrawal as a 25 percent partner, effective February 14, 1979. This action places Oxy in a 100 percent leasehold position.

Plans are to develop Tract C-b in a progressive fashion which will allow early evaluation of the modified in situ technology on the new site prior to construction of a full-scale commercial facility. Current plans call for constructing a small retort test area which can begin operations while development of the commercial mine and retorts is underway. It is expected that the first retort will be ready for processing by November 1980. When the commercial facility reaches full production in 1985, approximately 40 retorts will be in various stages of "burning" at the same time. This will produce a total of 57,000 barrels of shale oil daily. Utilizing Oxy's modified in situ technology will result in the production of approximately 1.2 billion barrels of the 3.0 billion barrels of shale oil in place on the tract. If it is determined that surface retorts can be used to process the mined out shale, total recovery will be about 1.65 billion barrels of oil. The process is expected to recover 34 percent of the total inplace resource, which consists of a 310-foot thick zone of 25 GPT oil shale. Occidental and Ashland estimate that the required capital cost of the Tract C-b oil shale facility will be $440 million. In turn, development of the tract will result in 1,600 permanent jobs for the duration of the 65-year project.

The White River Shale Project is a joint development of Tracts U-a and U-b in northeastern Utah. The lease on Tract U-a was awarded to Phillips Petroleum Company and Sunoco Energy Development Company (then Sun Oil Company) in May 1974. SOHIO Petroleum Company then joined Sunoco and Phillips to create the White River Shale Oil Corporation which was awarded a lease on Tract U-b in June 1974.

White River plans to follow a modular development approach in commercializing oil shale operations on Tracts U-a and U-b. The first major activity on the tracts will be to establish a room and pillar mine with its attendant access shafts. This Phase I developmental mine will better define the shale conditions existing on the tract which will have an effect on future large scale mining and processing operations. During this initial mining operation, about 30,000 tons of shale will be mined for crushing and retorting evaluations. During Phase II this exploratory mine will be enlarged to the point where it can produce about 10,000 tons of oil shale per day. This oil shale will subsequently be crushed and fed to a single commercial sized vertical retort. Successful initiation and operation of the single retort installation will be followed by engineering and construction of a commercial plant. For the commercial plant producing 100,000 barrels of shale oil per day, the mining operations will produce about 160,000 tons per day of raw shale.

White River estimates that the cost for commercial developments on Tracts U-a and U-b will be approximately $1.6 billion. Long-term commercial development will result in the creation of 2,050 permanent jobs. Because of the high costs involved, and because of the risks and uncertainty surrounding such a project, White River feels that the ultimate development of Tracts U-a and U-b may require government support. White River has recently proposed a $246 million modular demonstration plant to be funded via DOE. The demonstration plant would include both modified in situ and surface retorts. Future development on Tracts U-a and U-b, however, is clouded by a legal question concerning ownership of the leased lands. This issue is currently being considered by the courts, and no development on the tracts is likely until these issues are resolved.

OTHER COUNTRIES

Oil shale industries have existed at one time or another in 13 other countries. The first recorded production of shale oil was in Austria in 1350. A 14th Century British patent refers to deriving "a kind of oyle from a stone." The first recorded installation of oil shale retorts to produce oil as fuel was in France in 1838.

Two recurrent situations are noted in the history of oil shale development since 1838. First, development has only occurred under unusual, localized conditions, primarily where no viable sources of coal or crude oil were available or where they were inadequate. The second situation is that, until very recently, oil shale industries were at their best just before, during and immediately following World War II.

Only two significant commercial industries exist today--in Manchuria and Estonia. Several countries, including Australia, Brazil, Germany and Israel, are leaning toward industrial development of oil shale in the 1980's.

Australia

Australia has very large identified resources of greater than 10 GPT oil shale. The shales were deposited in coal swamps, in the

sea, and in lakes. Oil shale occurrences were first noted in Australia in 1802.

Oil shales associated with coal seams are widespread in Permian and Jurassic strata in Queensland and New South Wales. Their areal extent, individually, is small (tens of miles^2), but yields are high, 116 to 203 GPT. Many of these oil shales are unsuitable for open-cut mining because of thick overburden and extensive faulting. They are, however, relatively well situated geographically and are the only deposits to have been mined in mainland Australia.

Sporadic production took place in New South Wales from the mid-1860's until 1952. The main production was during war-time periods of oil shortages. Total production of shale oil amounted to about 700,000 barrels, mainly from Permian coal measures at the Newnes Capertee deposit near Glen Davis, approximately 93 miles northwest of Syndey. The plant featured the use of about 100 vertical kiln retorts patterned after the Scottish Pumpherston-Fell type. Each retort handled seven to eight tons of 70 GPT shale per day and recovered about 90 percent of the assay value of the feed shale. Operations proved to be uneconomical after World War II and the facilities were abandoned.

During the war, many "backyard" oil shale operation existed; one of these was operated by Lithgo Oil Party Ltd., at Marangaroo, New South Wales, and reportedly produced over two million gallons of oil at a time when every drop of liquid fuel counted.

The marine shales include a comparatively small deposit of Cambrian age at Camooweal in northwest Queensland, some small deposits of Permian age near Devonport in northern Tasmania, and an extensive deposit of Cretaceous age in the Toolebuc Formation which, at various depths, underlies an area of about 27,000 miles^2, extending south from the Gulf of Carpentaria to northern New South Wales and northeast South Australia.

Small quantities of shale oil were produced in Tasmania between 1910 amd 1934.

The Toolebuc oil shale has an average thickness of about 33 feet, an average yield conservatively estimated at 13 GPT, and contains minor amounts of vanadium, uranium, and selenium. The inferred subeconomic resources of oil equivalent in the Toolebuc Formation are large, on the order of 2,850 x 10^9 barrels. These inferred resources represent about 500 times as much oil as the current estimate of recoverable resources of conventional oil in Australia.

The Toolebuc Formation oil shale, despite its immense resources, is thought to have low potential for economic exploitation because of geographic location and limited availability of water for mining and processing. Development of in situ processing, which may require less water, could improve its economic prospects.

Lacustrine (lake bed) deposits occur in a number of Tertiary Basins in eastern Queensland, including the Rundle or the Narrows Deposit (the Narrows Graben) and the Duaringa Basin. Yields average less than 29 GPT, and areal extent is limited to a few hundred square miles. Individual beds in the Rundle deposit are less than 300 feet thick, but the aggregate thickness of oil shale beds and interbedded sedimentary rocks is several hundred feet. All of the lake deposits are in geographically favorable locations, and for this reason they appear to have the highest potential for exploitation.

The Sydney, Australia firms of Southern Pacific Petroleum and Central Pacific Minerals are proposing a three-retort plant to produce 23,300 BPD by 1981 from the Rundle oil shale deposit in central Queensland. The Union, Lurgi-Ruhrgas, and Superior processes have been selected for detailed engineering economic evaluation. Initial cost of the facility is estimated to be between $210 million and $240 million. Surface mining techniques would be employed. The Rundle deposit has proved reserves of 1.3 billion barrels.

By 1986, the project would grow to 40 retorts, producing 255,000 BPD with an investment of $2 billion. To make upgrading unnecessary, unhydrogenated shale oil costing $11 per barrel would fuel nearby power plants.

Austria

Production of shale oil was first recorded in Tyrol in 1350 A.D., but there are indications that this began even much earlier. Around 1600, shale oil or "rock oil" as it was called was discovered to have medical value and many primitive works produced oil for trading and local consumption. Shale oil production attained some economic significance in 1839 when an asphalt factory began operation. Between 1840 and 1882, oil shale was employed mostly for the extraction of asphalt mastic, naphtha, and asphalt tar. By 1900, the therapeutic value of shale oil was again recognized and since then has been produced solely for medical purposes in the field of dermatology. From 1937 to 1966, the annual use was about 600 tons. Some use of shale oil probably continues today, but the relatively small reserves and complicated mining situation leave significant oil shale use in Austria in doubt.

Brazil

Reserves of medium-quality Irati shale oil in Brazil are known to be adequate for an

extremely large industry, but large scale commercial exploitation was not seriously considered until after World War II. Nevertheless, it is known that illuminating gas was produced from oil shale in the Pariaba Valley as early as 1882. Small scale operations existed off and on thereafter until 1946.

In 1950, the Brazilian government launched a major research program to develop a practical technology for utilizing Irati shale. Bench scale and pilot plant studies during the 1950's and 1960's resulted in development of the Petrosix process. In addition to oil, the Petrosix process yeilds LPG, high-Btu fuel gas, and elemental sulfur; all are products of importance in Brazil.

Meanwhile, Brazil's oil shale was explored, in reconnaissance fashion, over most of the southern part of the country. Geologists ultimately selected a site near Sao Mateus do Sul in the southern part of the State of Parana for a concentrated exploration effort. Coreholes were drilled on a 100 meter grid pattern, reserves of some 200 million barrels were delineated, and plans were made in the mid-1960's to establish a demonstration Petrosix plant at this site.

Operation of the 2,200 ton-per-day demonstration plant began in 1973. The Petrosix retort installed at the plant was designed by Cameron Engineers. The retort is the focal point of an impressive complex that includes facilities for crushing, screening fines briquetting, oil separation, LPG and sulfur recovery from retort off-gas, and power production. A new town was established at nearby Curitiba, complete with attractive residences and schools plus all the necessary amenities such as a water and sewer system and roads paved with crushed oil shale.

A nearby surface mine provides shale to the plant, which is located near the oil shale outcrop. Oil shale is recovered from two beds near the surface but separated by a bed of barren limestone.

In 1976, the Brazilians had become experts at operating the plant and began serious studies of starting a large-scale commercial industry. The 2,200 ton-per-day retort, some 18 feet in diameter, may be used as the first in a battery of commercial-scale modules that would be built at the existing complex. But it is likely that Petrobras may seriously consider going to a retort twice the diameter and four times the throughput. In any event, it would be no surprise to hear Brazil announce firm plans for a large-scale industry before 1980.

Burma

The Burmese oil shale deposit is an extension of that in Thailand. Reserves are not large but quality appears to be good. There has never been any commercial production.

Canada

Oil shales from the maritime provinces were distilled to produce waxes and illuminating oils in the early 1800's, but no significant industry ever existed. Studies during the last decade have failed to provide an economical means of using Canadian shales from either Saskatchewan or the maritime provinces. Reserves are substantial but quality is marginal. The best use may prove to be for production or direct burning for power generation.

England

Jurassic Kimmeridge Clay, a 150-million-year-old formation underlies much of eastern England and the North Sea and has small outcrops in Scotland. In addition to the possibility of establishing a shale oil industry with this resource, current interest arises due to the belief that Kimmeridge Clay may be a major natural source rock in the North Sea oil province.

The existence of the Kimmeridge Clay oil shales has been known since the Iron Age. At various times since then they have been used as a coal substitute, and in the 18th Century they supplied the heat source for alum and seal-salt works at Kimmeridge, Dorset. Numerous attempts have been made to exploit the shales as a commercial source of oil. In the latter part of the 19th Century, several large consignments of shale were sent from Dorset to be retorted at the Scottish Lothians oil shale works. Although the yields of oil were considered to be satisfactory, the shale was more expensive to distill than Scottish shale, and the product oil contained an unacceptably high sulfur content.

In 1975, the U.K. Department of Energy recommended that the Institute of Geological Science (IGS) undertake a study of the oil shale occurrences in the Kimmeridge Clay. The institute had at that time already embarked on a pilot study of these oil shales in southern England in order to assess whether a full scale study of the occurrences throughout the U.K. would be worthwhile.

Kimmeridge Clay oil shales occur as thin seams (yielding 40 to 55 GPT) separated by barren clays (yielding less than three GPT). Even the thickest of the oil shales in the Kimmeridge Clay could not be readily mined close to the outcrop as in individual seam. In opencast workings whole groups of seams, together with the intervening barren clays, would need to be worked. It would therefore be advantageous if, immediately after excavation of the bulk material, a simple mechanical

technique could be found which would concentrate the oil shale seams to avoid retorting unproductive material. Enrichment by differential slaking provides just such a method on the laboratory scale and could form the basis for an industrial process.

No appreciable enrichment of trace elements has been detected in these oil shales. Analyses of spent shale indicate that it could probably be used for brickmaking and for fill in the construction industry. Some of the spent shale may have pozzolanic properties.

Because of its low strength, the Kimmeridge Clay could probably be worked at or near its outcrop only by opencast methods. Underground mining might be possible at depths greater than about 350 feet in the areas of thick Kimmeridge Clay deposits.

The Kimmeridge Clay contains the richest source of organic material in the British Mesozoic sequence and is almost certainly the major source of hydrocarbons in the North Sea oil province.

France

The world's first recorded production of shale oil for profit was in France in 1838. France's shale oil industry apparently flourished until the discovery of conventional liquid petroleum. After that, the French government from time to time provided various kinds of financial support such as duties on imports or direct subsidies. The French industry apparently used the Scottish Pumpherston retort almost exclusively after 1860 and until the 1940's when French-designed retorts replaced the smaller Pumpherston. Production apparently reached an all time high of 500,000 tons in 1947 but declined steadily thereafter. Still, three plants were in operation as late as 1950, each receiving indirect government subsidies of one kind or another. The industry ceased in the 1960's.

Germany

The first recorded utilization of oil shale in Germany was in 1916, but little is known of the early industry--it probably existed on only a pilot or experimental scale. By 1937, only one small plant was in operation. It consisted of a series of small vertical retorts held in masonry and externally heated with hot gases. Production was not large and the plant did not play an important part in subsequent developments in Germany. In 1940, oil shale operations began at a former portland cement plant at Dotternhausen.

Germany, of course, has large deposits of brown coal and lignite in addition to oil shale. During the 1930's the Hitler regime focused efforts on producing liquid fuels from coal and lignite. This resulted in improvements to the Bergius and Fischer-Tropsch processes and the installation of full-scale industrial plants. Early in World War II these synthetic fuels plants using coal seemed adequate to meet Germany's wartime needs for liquid fuels, but the situation quickly changed after the U.S. entered the war and bombing raids began to take a heavy toll. The situation in Germany for expanding an oil shale industry during the war was, of course, entirely unique. It was only necessary to issue an order to that effect with no concern for economic viability. Instead of developing plans similar to those of existing plants, however, the group given responsibility for oil shale directed their efforts toward in situ recovery. Some technology was developed, but the overall effort was unsuccessful and little shale oil was ever produced.

Meanwhile the Dotternhausen plant was damaged by bombs during the war and operations had ceased. In 1943, Lurgi began construction of an oil shale plant at Frommern but it was never completed. Both of these projects were resurrected after the war and by late 1947 both plants were back in operation with a combined production of 1,500 tons-per-day. The Lurgi plant was equipped with Schweitzer retorts whereas the Dotternhausen plant utilized Meier-Grollman retorts. Both plants were located in the Province of Wurttenberg.

There is the possibility that sometime in the 1980's Germany may decide to build a pilot plant capable of retorting 500,000 metric tons of oil shale per year. A government/industry group, composed of Veba-Chemi, Lurgi AG, and state-owned Braunschweighische-Kohlenberg-werke, is currently conducting laboratory-scale recovery tests in Braunschweig. The pilot plant may be followed by a demonstration plant with a capacity of five million metric tons per year. Depending on economics, a 60 million metric ton-per-year plant might be built in the late 1980's or early 1990's for an estimated $1.3 billion.

Israel

Oil shale occurences are known to be widespread throughout Israel. The most important deposit delineated to date is called the Zefa-Ef'e, and is located in the Negev desert. Reserves established here amount to over 600 million tons and average 14 weight percent organic matter. The thickness of this oil shale ranges from 100 to 200 feet, with a shale-to-overburden ratio of 1:1. A particular advantage of this deposit is its location near the industrial centers of Rotem and the phosphate mines and processing plants at Oron and Nahal Zin. These industries currently consume 200,000 metric tons of imported fuel oil per year, a requirement that could be met by oil shale conversion.

Israel has an electrical generation capacity of 1,800 megawatts and depends entirely on imported fuel oil. A coal-fueled power generating plant is currently under construction on the coast north of Tel Aviv. This new plant will burn coal imported from South Africa. Additional expansions of the power industry are contemplated.

The yield of liquid oil from Israeli oil shale is rather low, being about 43 weight percent of the shale's organic (kerogen) content. The sulfur content of the shale is high, being about 10 percent. The inorganic matter in the shale consists mostly of calcium carbonate. The Israeli's interest in direct combustion of shale stems from their desire to extract the maximum amount of heat from the kerogen, rather than leave unrecovered heat (possibly 40 percent of the total) in the form of residual carbon on spent shale solids remaining after retorting. Mitigating against direct combustion of shale in boilers is the fact that if flame temperatures are high, much heat will be lost in decomposing calcium carbonate. If flame temperatures are low, boiler operation may be inefficient.

Jordan

A thorough exploration program was conducted during the past decade with financial and technical assistance from the U.S. and British governments. An excellent deposit of high grade shale has been identified but political problems have inhibited further development efforts.

Morocco

Two known oil shale deposits with development potential are located in two areas of Morocco. One deposit is about 50 km from Marrakesh and about 150 km from the Atlantic Coast, and the second deposit is about 100 km north of Western Sahara and 50 km from the Atlantic Ocean. In January 1979, Morocco and Occidental Petroleum Corporation reached agreement for development of the shale using Occidental's proprietary in situ process. Successful completion of the project would result in a 50,000 barrel per day facility.

New Zealand

The existence of oil shale in New Zealand has been known for several generations. Shale oil was even produced in small quantities from time to time beginning in about 1900, but significant production was never achieved. Studies during the past five years indicate deposits are too small and low quality.

Peoples Republic of China

A 450-foot thick oil shale deposit overlies one of the world's thickest coal deposits in the vicinity of Fushun in Liao-ning Province of Northern China. The oil shale may never have been commercially exploited except for the fact that it exists as overburden which had to be removed to reach the coal deposit. The Japanese began commercial utilization of the oil shale at Fushun in 1926. Shale oil was a principal source of liquid fuels for Japan during World War II.

The Fushun industry was in full operation in 1970 with a reported crude shale oil production of two million tons annually, from 30 million tons of oil shale. This is equivalent to some 15 million barrels per year, or about 40,000 barrels per day.

Today, the Fushun open pit mine is immense, measuring 1.4 miles by 1.37 miles. Production is 3.6 million tons per year of coal and 12 million tons per year of oil shale. Only shale of more than 4.7 weight percent organic material is retorted. This shale is orange in color. (This organic content compares with 4.0 weight percent for 10.5 GPT oil shale from the Green River Formation.)

There are two retorting complexes at Fushun. The older plant was built in 1941 under Japanese occupation forces. The second plant was built in 1954 using similar, but improved technology. The second plant comprises 60 vertical kiln retorts. Each retort is 13 meters (43 feet) tall, with an inner diameter of three meters and an outer diameter of four meters. Shale crushed to between one and seven cm is fed into the top, and air is forced in from the bottom. Operation is at atmospheric pressure. Residence time is an incredible nine hours. A discharge grate at the bottom of the retort rotates at less than one revolution per hour. Maximum temperature is 900-1000°C about one meter above the grate. Spent shale exits at 400°C and is quenched with water.

The spent shale has 2 percent residual coke. There is no apparent agglomeration. Spent shale is used for roads, mine fill, and in cement production. Wastewater is treated to remove pyridine, but by-products are dumped into a canal that eventually flows into a river.

Product shale oil from Fushun is refined at nearby small plants. A large refinery in Fushun used to process the shale oil, but it now processes crude petroleum from the Taching field, north of Fushun, which in 1959 became the first major PRC oil find. The Taching reserves are estimated to be about 8.4 billion barrels.

A second oil shale operation is located at Maoming in Canton Province, where annual production is 570,000 barrels. This project is similar to the operation at Fushun, except that there is no coal production.

Romania

A team of government technologists has been studying oil shale prospects for the past five years in an area near the Yugoslav border. Technical assistance has been sought in the U.S., but mining conditions are unfavorable and shale quality relatively poor.

Scotland

Scottish oil shale deposits are widely spread over parts of southeast Scotland (the Lothians), totaling about 175 square miles. The deposit is found in the Upper Calciferous Sandstones of Carboniferous age.

The Scottish oil shale industry began around 1860. Sometime shortly after that, more than 140 companies and individuals were engaged in oil shale ventures. The industry, which supplied products for the home, grew and prospered until the decreasing cost of imported petroleum reduced profits. In addition, the advent of synthetic ammonia made the production of ammonium sulfate as an oil shale by-product unprofitable. To survive, many of the small industries were absorbed by larger ones. By 1870 when production had reached 800,000 thousand tons annually, there were some 50 oil shale companies operating. The number was reduced to six by 1910 when production reached three million tons annually. Production hit an all-time high in 1913: 3,280,000 tons, or about 4,400 barrels per day. In 1910, the average yield was approximately 20.4 gallons of oil product per tons of shale. By 1920, all oil shale operations in Great Britain were consolidated under one parent company, Scottish Oil Ltd., which later became a subsidiary of the Anglo-Iranian Oil Company.

The Scottish industry continued at a relatively good pace after that, although production gradually decreased. Diesel oil and gasoline were the principal products but tars and waxes were also produced in significant quantities. A good-sized soap plant even operated during the late 1930's and early 1940's. In 1947, 12 mines, four retorting plants and a central refinery were in operation, but production by that time had decreased to 1.4 million tons per year. Although the industry did not receive direct government subsidies during this period, a portion of the diesel and gasoline taxes were remitted to the company to encourage production. Nevertheless, the post-war fate of the industry was inevitable. British Petroleum (BP) Company replaced Scottish Oils Ltd. as the oil shale operator in the early 1950's. Production declined sharply to about 826,000 TPY, and became progressively less profitable. BP conducted some in situ recovery experiments during this period, but with little success. Finally, BP decided in 1964 to suspend oil shale operations, which by that time were not profitable at all. The mines were plugged, and the retorting, transportation, and refining facilities were dismantled and mostly scrapped. The work force, which had numbered 900 in 1962, was disbanded.

The Scottish shale was extracted mainly by underground mining using inclined shafts, which followed the seams downward. From these seams, the average thickness of which was 1 to 1-1/2 yards, shale was extracted by pick and shovel and by blasting from shotholes. The material was conveyed to the surface, crushed, and retorted.

Originally the retorts were simple, horizontal tubes of oval, rectangular, or D-shaped cross section. These horizontal retorts were filled and emptied at one end through an iron door; a vapor offtake pipe was at the other end. These batch retorts were loaded and discharged manually, and they were eternally heated (to around 1,400°F) by coal.

The horizontal retorts were soon superceded by vertical retorts, and although the original ones were also batch-type, they were more efficient. In early types the process heat was obtained from burning producer gas from coal and combustible gas from the shale. Arrangements were introduced in 1878 by which the fixed carbon of the spent shale was utilized as fuel.

In 1882 a vertical retort was patented by Young and Beilby which gave semicontinuous operation. Steam injection was also employed to recover ammonia fertilizers.

In 1894, the Pumperston Retort was patented by Bryson, Jones, and Fraser. This design permitted the combustion of residual carbon by injecting air as well as steam and improved thermal efficiency and throughput. From the overhead product of combustion, crude oil, crude naphtha, ammonia liquor, and recycle fuel gas were produced. Throughput of the retorts was approximately 12 tons of shale per retort per day. The Westwood Retort, erected in 1941, marks the highest development in the design of the Pumperston-type retort.

It has been estimated that the Scottish oil shale industry extracted about 140 million tons of shale, mostly from underground mines. In the early years this material yielded up to 45 GPT, but shale with yields of less than 20 GPT was worked as richer seams became exhausted.

Initially no use was seen for spent shale, and it was simply piled into large slag heaps, locally known as "bings." These heaps, containing probably more than 100 million tons of material, occupy large tracts of land and are to this day a conspicuous feature of the landscape in the Lothians. Since about 1930, bricks have been manufactured from this material, and it has recently been used to form road embankments.

Reserves of about 75 million tons of oil shale are believed to be present in the Lothians, but much is low grade and working would be considerably hampered by the erratic nature of the old mines, most of which are water-filled and in a state of collapse. If all of this shale could be extracted, it would yield about 6.8 million tons of oil, the equivalent of less than four weeks' supply of U.K. oil needs.

Sicily

Oil shale has never been developed commercially in Sicily. A large deposit of medium grade shale is indicated, but it has never been thoroughly evaluated.

South Africa

A small deposit of high grade shale at Ermelo was developed commercially in 1935. The reserve was eventually depleted and operations ceased a few years ago. A search for new deposits has been unsuccessful to date.

Spain

Spain's oil shale deposit is relatively small. A small plant was built in 1922 by the Penarroya Company at the country's principal deposit near Puertollano about 120 miles south of Madrid. The Penarroya plant was operated off-and-on for the next 30 years. Production from the plant was never large, perhaps no more than 100 to 200 barrels daily.

The National Industrial Institute of Spain created a new oil shale company in 1942 and development work was begun in the Puertollano area. It probably encompasses the older Penarroya plant or replaced it altogether. In any event, the new plant was referred to as the Calvo Sotelo Plant. It was completed in 1955, but its retorts were both outdated and uneconomical. The operators were eventually integrated with a new refinery using imported petroleum. It is doubtful that shale oil is still being produced today.

Sweden

The oil shale deposits in Sweden have been subjected to relatively intensive geologic investigation over the years. They are scattered throughout the country and are small but reasonably good quality reserves. About 1920, an experimental oil shale plant was erected at Kinnekulle with government support. The plant was a technical success but it was later shut down for economic reasons. Nevertheless, the retort used in this operation was an important development and was the basis for later industry developments.

During World War II, Sweden found it necessary again to turn to shale oil production and a much larger plant was built at Kvarntorp, entirely at government expense. The shale deposits at Kvarntorp consist of two layers, each 20- to 25-feet thick. The upper layer yields about 13 gallons of oil per ton and the lower layer yields about 18 gallons of oil per ton, when retorted. Above the shale, there is usually a bed of limestone. An open pit mine was opened at an outcropping of shale and an in situ operation was conducted nearby where a gas-tight limestone capping was present on the shale bed. The original plant included three Bergh retorts, two IM tunnel kilns, one HG retort, a Ljungstrom method in situ operation, condensation equipment, shale quarry, topping plant, refinery, steam power plant, sulfur recovery plant, and tank farm. The plant had a capacity of about 260 barrels daily during the war.

The Ljungstrom in situ method featured electrothermal heating of shale in place. The field was prepared by draining off groundwater and drilling holes for emplacement of heating elements and for oil vapor collection. Holes were arranged in a hexagonal pattern with 7-foot spacings. Electric power came from the company's own steam power plant as well as from public power lines. The heating period lasted for about five months. The shale attained 550°F after three months and 700°F after five months. Shale oil vapors and gases seeped toward the gas vapor wells and reached the condensers under pressure created by the in situ field. By bringing in additional areas, a heat wave was made to pass through the shale at a rate of about 500 feet per year.

The plant was improved after the war and by 1947 was producing shale oil at about 1,600 barrels per day. Post-war economics finally caught up with the plant, however, and shale oil production was phased out in 1963, although the refinery and by-product facilities continued operation on imported oil feedstocks.

Thailand

Studies of Thai oil shale were begun fairly recently by a consortium of Thai, Japanese and U.S. interests. A significant deposit of rich shale is indicated, making the long term outlook reasonably good. But commercial production has never been achieved and there is no active project known to exist today.

USSR

USSR oil shale history is, for the most part, Estonian oil shale history. Estonian oil shale, known as kukersite, is among the richest oil shale in the world and sufficient reserves exist for a very large industry. Most Kukersite processed by the Soviets exceeds 40 gallons per ton. The two principal uses to date have been as a boiler fuel by simply burning the shale and as a source of combustible, low Btu town gas primarily for use in Leningrad. Lately, the

Soviets have been directing their R&D efforts towards the production of oil and chemicals.

The history of the Estonian oil shale industry began in 1920, three years after the nation was freed from imperialist Russian rule. Research and development was conducted during the following several years, and in 1925 the State Oil Shale Industry erected a plant with a capacity of 200 tons per day. The Pintsch-type retort installed in the plant was used for production of low Btu town gas and was no doubt the progenitor of the modern day gas generator known as the Kiviter retort.

Two years later a company known as the Oil Shale Syndicate built the first tunnel oven. Then, in 1930 and 1931, two tunnel ovens or kilns were built at the Estonian Mineral A-G plant. They each had a capacity of 250 tons. The tunnel kiln results were so encouraging that two more were built in 1936 and 1937, each having a capacity of 400 tons. The tunnel kilns were batch-type processes wherein as many as 18 shallow hopper cars loaded with oil shale to a depth of about one foot would pass through a rectangular-shaped steel tunnel several hundred feet long. Hot gases would be passed through the shale beds and gas and oil recovered. All of the evolved gas and some of the oil was needed to produce heat for the process, so it was relatively inefficient. Even so, tunnel ovens were used until the late 1960's.

The New Consolidated Gold Fields Company started R&D of another process in the late 1920's, including pilot plant work in England. In 1931, it built a plant containing eight externally heated rotary retorts with a combined capacity of 200 tons per day. The Davidson rotary retort (named after its English designer) was the forerunner of the present day Galoter retort and is similar to the TOSCO II retort in that it employed indirect heating of oil shale. Carbon or spent shale was burned to provide retorting heat.

The estonian oil shale industry was thus well established by the late 1930's. Production reached nearly 800,000 tons in 1938, second only to Scotland. But war was on the way. Estonia was occupied by Russia in 1929. While the existing industry was not severely hampered, any expansion plans were likely curtailed. In 1941, Germany invaded Estonia and the Russians disabled the entire industry as they withdrew to the east. The Germans immediately developed plans to restore the industry using local materials and to greatly expand it using plants designed and fabricated in Germany. They never had a chance to get started. Russia regained possession of Estonia in 1944. They apparently assumed the German plans for expanding the oil shale industry also. The Russian 5-year program called for 9.4 million tons of production annually. That goal was probably not reached; however, at least one new plant was completed during the 1950's.

During the 1960's, an impressively large R&D program was carried out to develop the Kiviter and Galoter processes. Two large demonstration plants (1,000 TPD) were built in the early 1970's and are still being operated today. Even large retorts are being designed and may now be under construction. Licensing of the Kiviter and Galoter is now being pursued in the U.S. through the Soviet Licensitorg. Resource Sciences Corporation of Tulsa has played a role in this effort.

The oil rotary retorts and tunnel ovens were phased out before 1970, but 1971 production in Estonia was estimated at 18.1 million tons, or about 50,000 tons per day. In 1978, it was reported that 30 million tons of oil shale were extracted for the year 1977, and the Oil and Gas Journal reported that 50 to 60 million tons annually is the goal by the end of the decade.

The principal use of Estonia Kukersite today is as a fuel burned directly in electric power generation. While shale production in Estonia represents only about 1 percent of total USSR fuel requirements, it accounts for some 90 percent of Estonian power production. Two-thirds of all oil shale mined in Estonia is burned directly in power plants; the remainder is processed to obtain fuel oil, gasoline, town gas primarily for Leningrad, and various chemicals.

Another oil shale area in the USSR thought to be receiving some attention is the lower Volga region. There probably was some development there during the 1930's and it may even have approached the size of the Estonian industry at one time. During recent conversations with Soviet technologists, however, this region was not mentioned.

Zaire

Production of oil shale in Zaire has never been achieved and recent attempts at exploration and evaluation of deposits have been interrupted by political events. However, reserves of high grade oil shale are indicated to be large.

Appendix D

POLLUTION CONTROL GUIDANCE FOR OIL SHALE DEVELOPMENT: ABSTRACT AND TABLE OF CONTENTS

ABSTRACT

This document originated as a result of the Environmental Protection Agency (EPA) concern that the development of oil shale as an alternative energy source not be constrained by uncertainties about environmental standards. It is the intent of EPA to ensure that technology-specific environmental goals are identified and reached during the course of oil shale technology development in order to avoid delays and allow establishment of a mature oil shale industry which is compatible with national environmental goals.

The EPA envisions this document as the first of a series leading toward the establishment of regulatory standards for the oil shale industry. The series is expected to serve several purposes. First and foremost, it will serve to communicate EPA regulatory policies to oil shale developers on a comprehensive basis. Second, the series will update the state of knowledge with respect to known oil shale pollutants and their potential effects. Third, the series will describe state-of-the-art control technologies as they evolve and will describe the remaining needs where technologies are not sufficient. Fourth, the series will describe monitoring methodology and methods for sample collection and analysis applicable to the oil shale industry. Finally, it will suggest ranges of discharge and emission limits within which the oil shale industry should strive to operate. Ideally, as more information becomes available, each document in the series will offer more definitive limits and more demonstrated confidence in available control technologies. The series would culminate in a document providing the basis for legally defensible regulations.

This document presents general information relevant to oil shale pollution problems and their control as they are viewed today. It should be kept in mind that the present data base is meager and that attempts to precisely define problems and their control will be incomplete. The purpose is to present a first approximation of EPA's regulatory expectations and thereby to generate, through their publication, the proper perspective, concern, and approach for oil shale pollution control.

The Production Control Guidance for Oil Shale Development document will be available in the Summer of 1979, but its table of contents is presented to give an idea of its scope.

POLLUTION CONTROL GUIDANCE FOR OIL SHALE DEVELOPMENT

TABLE OF CONTENTS

VOLUME I

I. Introduction
- A. Purpose of Paper
- B. Oil Shale Resources
- C. Oil Shale Regions
- D. Current Status of Shale Industry Development
  - References (I-B,C,D)
- E. Applicable Current Federal and State Pollution Control Laws
- F. Proposed EPA Regulatory Approach

II. Recommendations
- A. Proposed Precommercial Approach to Regulations
- B. Designated and Non-Regulated Pollutants
- C. Proposed Monitoring Procedures
  1. Air Emissions
     - References
  2. Surface and Groundwater
  3. Solid Waste
- D. Improvements in Control Technologies
- E. Recommended Research

III. Environmental Impacts
- A. Atmospheric Impacts
  1. Inventory of Process Emissions
  2. Residual Atmospheric Emissions
  3. Fugitive Dusts
  4. Trace Elements
     - References (III-A-1,2,3,4)
  5. Atmospheric Transport and Fate
- B. Water Quality Impacts
  1. Sources and Nature of Waters for Oil Shale Processing
  2. Effects of Wastewater Disposal on Surface Waters
     - Bibliography
  3. Effects of Wastewater Disposal on Groundwaters
  4. Long-term Regional Effects
     - References
- C. Solid Waste Impacts
  1. Inventory of Solid Wastes
     - References
  2. Raw Shale Handling and Disposal
     - References
  3. Spent Shale Handling and Disposal
     - References
  4. Other Solid Process Wastes
  5. Leaching of Solid Wastes
     - References
- D. Health Impacts
  - References
- E. Other Environmental Impacts
  1. Shale Products Utilization
     - References
  2. Radiation
  3. Noise--On and Offsite
  4. Social/Economic Impacts
     - References

IV. Pollution Control Technology
- A. Air Emission Controls
  1. Particulates Control
     - References
  2. Gaseous Emissions Control
     - Bibliography
- B. Wastewater Treatment Controls
  1. Wastewater Treatment Methods
  2. Wastewater Sources, Quantities and Characteristics
  3. Application of Treatment Methods to Oil Shale Wastewaters
     - References
- C. Solid Waste Controls
  1. Surface Disposal of Overburden, Lean Shales, Raw Shale Fines, Spent Shales, Chemical Solids
     - References
  2. Underground (Mine) Disposal of Spent Shale
  3. Stabilization of In Situ Spent Shale
     - References
  4. Leachate Treatment and Recycling
- D. Other Process Controls
  1. Storage Tank Vapor Controls
  2. Refinery Sludges

V. Sampling, Analysis and Monitoring of Emissions, Effluents, Solid Wastes
- A. Air
  1. Gases-Inorganics
  2. Particulates
     - References (V-A-1,2)
- B. Surface and Groundwater
  1. Monitoring Methodology
     - References
  2. Standard Water Tests
     - References
  3. Organics
     - References
     - References

POLLUTION CONTROL GUIDANCE FOR OIL SHALE DEVELOPMENT

TABLE OF CONTENTS (Continued)

C. Solid waste
   1. Monitoring Methodology
      References
   2. Organic Leachates
      References
      Inorganic Leachates
      References
   3. Solid Inorganics
      References
   4. Solid Organics
      References
   5. Bioassays
   6. Groundwater Monitoring Near Disposal Sites

VI. Suggestions for Development of Interim EPA Emissions, Effluent and Solid Waste Disposal Standards
   A. Standards Criteria and Environmental Goals
   B. Suggestions for Interim Regulatory Guidelines and Standards
      1. Air Emissions
      2. Water Effluents
      3. Solid Wastes
   C. Industry View of Regulation

VII. Summary of Major Retorting Processes, Emissions, and Effluents
   A. Overview of Shale Technology
      1. Mining
      2. Crushing, Storage, Transport
      3. Surface Retorting
      4. In Situ Retorting
      5. Spent Shale Disposal
      6. Retort Gas Treatment
      7. Shale Oil Upgrading
   B. Retorting Processes
      1. Colony/TOSCO Development
      2. Paraho Development
      3. Union Oil Development
      4. Superior Oil Development
      5. Lurgi-Ruhrgas Process
         References

VOLUME II

Appendix A - Status and Development Plan of the Oil Shale Industry

Appendix B - Procedures for Ambient Air Monitoring

Appendix C - Past, Present and Future Baseline Monitoring Activities

Appendix D - Federal, State, and Local Laws and Regulations Applicable to Oil Shale

Appendix E - List of Analytical Procedures Manuals and Quality Assurance Manuals

Appendix F - Catalog of Existing Federal, State and Locally Required Permits

Appendix E

ABBREVIATIONS

AOSO	Area Oil Shale Office, USGS
BMI/PNL	Battelle Memorial Institute Pacific Northwest Laboratories
BNL	Brookhaven National Laboratory Brookhaven, New York
DOE	Department of Energy
DRI	Denver Research Institute
ECTD	Emission Control Technology Division, Office of Air, Noise and Radiation, EPA Ann Arbor, Michigan
EERC	Energy and Environmental Research Corporation, Santa Ana, California
EMSL-Ci	Environmental Monitoring and Support Laboratory, EPA Cincinnati, Ohio
EMSL-LV	Environmental Monitoring and Support Laboratory, EPA Las Vegas, Nevada
EMSL-RTP	Environmental Monitoring and Support Laboratory, EPA Research Triangle Park, N. C.
EPA	Environmental Protection Agency
ERIC-Ci	Environmental Research Information Center, EPA Cincinnati, Ohio
ERL-Athens	Environmental Research Laboratory, EPA Athens, Georgia
ERL-Duluth	Environmental Research Laboratory, EPA Duluth, Minnesota
ERL-Gulf Breeze	Environmental Research Laboratory, EPA Gulf Breeze, Florida
HERL-RTP	Health Effects Research Laboratory, EPA Research Triangle Park, N. C.
IERL-Ci	Industrial and Environmental Research Laboratory, EPA Cincinnati, Ohio
IERL-RTP	Industrial Environmental Research Laboratory, EPA Research Triangle Park, N. C.
LASL	Los Alamos Scientific Laboratory, Los Alamos, New Mexico - (Under the DOE)
LBL	Lawrence Berkeley Laboratory Berkeley, California (Under the DOE)
LETC	Laramie Energy Technology Center, Laramie, Wyoming (Under the DOE)
LLL	Lawrence Livermore Laboratory, Livermore, California - (Under the DOE)
NBS	National Bureau of Standards
NIEHS	National Institute of Environmental Health Sciences, Research Triangle Park, N. C.
NIOSH	National Institute of Occupational Safety and Health
NIEHS	National Institute of Environmental Health Studies (DHEW)
OEMI	Office of Energy, Minerals and Industry, within the Office of Research and Development, EPA
OEMI-Hq.	Office of Energy, Minerals and Industry, Headquarters, EPA Washington, D.C.
ORD	Office of Research and Development, EPA
ORNL	Oak Ridge National Laboratory, Oak Ridge, Tennessee - (Under the DOE)
OSWG	Oil Shale Work Group, Gene Harris, Chairman, EPA-Ci
R.S. KERR	Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma
TOSCO	The Oil Shale Corporation
UCLA	University of California at Los Angeles
USBM	U.S. Bureau of Mines, Department of Interior
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey, Department of Interior

Appendix F

GLOSSARY

BACT - (Best Available Control Technology) The level of pollution control technology that a new or modified major pollution source, which is located in an area designated as meeting ambient air quality standards, must install.

Bioassay - Determination of the relative effective strength of a substance by comparing its effect on a test organism with that of a standard preparation.

Carcinogen - Any agent that incites development of a malignant epithelial tumor.

Cascade Sampler - A low-speed impaction device for use in sampling both solid and liquid atmospheric suspensoids: Consists of jets (each of progressively smaller size) and sampling plates working in series and designed so that each plate collects particles of one size range.

Chromatin - The deotyribonucleoprotein complex forming the major portion of the nuclear material and chromosomes.

Coal Liquefaction - The process of preparing a liquid mixture of hydrocarbons by destructive distillation of coal.

Consent Decree Pollutants - A list of sixty-five (65) toxic chemicals for which EPA is required to develop limitations and standards. For some rule making purposes EPA has redefined the list of 65 broad chemicals/chemical classes to 129 more specific chemicals.

Criteria Pollutants - Those pollutants for which EPA has promulgated ambient air quality standards and for which state implementation plans exist. (SO, CO, NO_x, O_3, Hydrocarbons, Particulates, Lead).

Cytochemical - Any of the complex protein respiratory pigments occurring within plant or animal cells.

Cytology - A branch of the biological sciences which deals with the structure, behavior, growth, and reproduction of cells and the function and chemistry of cell components.

Cytotoxin - A specific substance, usually with reference to antibody, that inhibits or prevents the functions of cells, or causes the destruction of cells, or both.

Devonian Deposit - A geological formation deposited during the Devonian period some 350 to 400 million years ago.

DNA - Deoxyribonucleic acid; any of various nucleic acids that yield deoxyribose as one product of hydrolysis, are found in nuclei and genes, and are associated with the transmission of genetic information.

Electrophoresis - The migration of charged colloidal particles through the medium in which they are dispersed, when placed under the influence of an applied electric potential.

Enzyme - A catalytic substance, protein in nature, formed by living cells and having a specific action in promoting chemical change.

Epithelial - Pertaining to the tissues which cover free surfaces (skin) or lining of body cavities and ducts.

Epithelium - A cellular animal tissue which covers the free surface that lines a tube or cavity; which consists of one or more layers of cells forming a sheet practically unbroken by intercellular substance; and either smoothly extended or much folded on a basement membrane and compacted, which, serves to enclose and protect other parts of the body.

Fugitive Dust - Any form of particulates which become transported as a result of wind or mechanical operations. Typical mechanical generators are vehicles, crushing machines and earth movers.

Gas Chromatography - A separation technique involving passage of a gaseous moving phase through a column containing a fixed adsorbent phase; it is used principally as a quantitative analytical technique for volatile compounds.

Gel Permeation Chromatography - Analysis by chromatography in which the stationary phase consists of beads of porous polymeric material such as a cross-linked dextran carbohydrate derivative sold under the trade name sephadex; the moving phase is a liquid.

High Pressure Liquid Chromatography - A separation technique employing a pressurized solvent as a moving phase through a column containing a solid support.

High-Volume Sampler - A sampling device consisting of a filter and a high volume air pump used for the quantitative collection of airborne particulate materials.

Hydrocarbon - One of a very large group of chemical compounds composed only of carbon and hydrogen; the largest source of hydrocarbons is from petroleum crude oil.

In Situ - In the original location.

In Vitro - Pertaining to a biological reaction taking place in an artificial apparatus.

In Vivo - Pertaining to a biological reaction taking place in a living cell or organism.

Lavaging - The washing out of an organ.

Macroinvertebrate - A large animal lacking an internal skeleton.

Mesozoic Deposit - A geological formation deposited during the Mesozoic era some 60 to 230 million years ago.

Mississippian Deposit - A geological formation deposited during the Mississippian period approximately 310 to 345 million years ago.

Mutagenesis - An agent that raises the frequency of mutation above the spontaneous rate.

Oil Shale - A finely layered rock that contains kerogen and from which liquid or gaseous hydrocarbons can be distilled. Also known as kerogen shale.

Permian Deposit - A geological formation deposited during the Permian period approximately 230 to 280 million years ago.

Phagocytic Activity - The process of engulfing and carrying particles into the cytoplasm of an ameboid cell.

Priority Pollutants - See Consent Decree Pollutants.

Quality Assurance - A system for integrating the quality control planning, assessment, and improvement of all works dealing with quantitative measurements.

Retorting Operation - Process of extracting shale oil from the raw shale by heating.

Spent Shale - (Retorted Shale) The shale residue after the shale oil has been extracted.

Teratogen - An agent causing formation of a congenital anomaly or monstrosity.

Tertiary - The older major subdivision (period) of the Cenozoic era, extending from the end of the Cretaceous to the beginning of the Quaternary, from 70,000,000 to 2,000,000 years ago.

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16. ABSTRACT

This report provides the reader with an overview of current oil shale research and development (R&D) efforts being performed by EPA, or being funded by EPA monies passed-through to other Federal agencies under the five-year old 17-agency Interagency Energy/Environment R&D Program.

Chapter 1 introduces the reader to the purpose, background and rationale behind EPA's efforts;

Chapter 2 discusses the EPA program goals and fiscal year 1978 program funding broken out in the areas: Extraction and handling, processing, energy-related processes and effects, and overall assessments, and;

Chapter 3 presents the scope-of-work and status for all of the ongoing projects. A table at the end of Chapter 3 summarizes these projects by presenting project title, sponsoring agency, performing organization, project duration and project contact.

Appendices are included which present world resources and development history, EPA-published reports on oil shale, general references on oil shale and a glossary of referenced terms.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS			b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group	
Air pollution	Funding	Oil shale	Anvil Points	Pollution Control Guidance Document	04B	06P
Air quality	Ground water	Pollution	Colorado	Research & Development	06A	06T
Aquifers	Health effects	Processing	Control Technology	TOSCO	06C	08H
Ecology	Hydrology	Shale oil	Environmental Assessment	Uintah Basin	06E	08I
Extraction and handling	In-situ	Spent shale	Integrated Assessment	Utah	06F	13B
Fossil Fuels	Land reclamation	Synthetic fuels	Paraho	World Resources	06J	
Fugitive dust	Mining	Water pollution	Piceance Basin	Wyoming		
	Monitoring	Water quality				

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